Astronomy and Astro-Physics.

NEW SERIES, Vol. XII, No. 1. JANUARY, 1893. WHOLE No. 111

General Astronomy.

ON THE PROBLEM OF THE SOLAR MOTION.*

TRUMAN HENRY SAFFORD.

In some papers presented in 1874 and the following year to the American Academy of Arts and Sciences at Boston, I pointed out that the hypothesis which makes the stellar distances on the whole inversely proportional to the star's proper motion is far more probable than that which assumes that these distances are a function of the star's magnitude. We can at once see the disagreement between the facts of the solar system and a hypothesis like the latter; while the nearest planet to us is also the brightest the most distant one is by no means the faintest; and there is no very definite relation between distance and brightness in the cases of Mars, Jupiter, and the asteroids.

On the other hand the average rapidity of angular motion among the planets as seen from the earth is more definitely connected with the distances.

In testing the theory that the star's distance is roughly a function of the annual proper motion, I very soon found that the individual discrepancies were pretty thoroughly masked by the general law when the stars were grouped by tens or twenty-fives according to the magnitude of their proper motions. In other words the average parallax of a group of twenty-five stars whose proper motions are nearly equal, but whose positions are in widely different parts of the heavens will (very nearly) be the same fraction of the annual proper motion as holds good for another group of stars of nearly equal proper motion, one-tenth as great as in the first group. The reasoning upon which this conclusion was based is derived from a study of that fraction of the total proper motion which simply reflects the Sun's motion towards Hercules and Lyra.

Mr. W. E. Plummer, in 1883, while investigating the Solar motion from the southern proper motions determined at the Cape of

* Communicated by the author.

XUM

Good Hope (see vol. 47 of the Memoirs of the Royal Astronomical Society, pages 340 to 343), adopted my hypothesis and compared it with the other; and found my conclusions sustained.

In 1890 appeared Dr. Stumpe's investigation of the Solar Motion (vol. 125 of the *Astronomische Nachrichten*), which led by a different way to about the same result. We may then consider the hypothesis as highly probable; and that the dependence of distance upon apparent magnitude is much less so; because in the earlier investigations the sum of squares of proper motions is very slightly diminished, on the whole, on the one theory; and by a large percentage on the other.

My present object is to point out what I think the right way to proceed in future.

We can, without hesitation, transform our coördinates in such a manner that the pole of the system, or axis of Z, shall be in an assumed direction of the Solar motion. This direction is now known within a few degrees. The advantage of this process is that the material shows its character more distinctly; the motion from the pole toward which the Sun is moving is at once seen to prevail, on the average; and the effect of the slight corrections to the direction of this point, afterwards to be applied, can be readily calculated. The transformation of coördinates thus indicated is analogous to that well-known one in orbit work when the plane of the approximate orbit is made the fundamental plane, a transformation which, in 1859, I believe I was the first to employ.

In studying the gradual decrease, along with proper motion itself, of the reflection of the solar motion, it is necessary to employ the smaller proper motions as well as the larger. Dr. Stumpe went down to 0″.16 yearly. Argelander in 1830, went as far down as 0″.09; and for Bradley's stars it is quite probable that the lower limit might now be no more than 0″.05 or 0″.06. But a careful investigation needs to be made of this lower limit, as it is dependent upon the observations available, and in some degree on the constant of precession; so that the systematic corrections and probable errors of the different authorities, and the corresponding weight, need to be taken account of in making the necessary least square solution. The investigation is one which requires a great deal of patience.

In determining star-places for practical purposes we frequently obtain proper motions which cannot be considered certain. That is, the value obtained by a least square solution, is less than its probable error, or does not much exceed it; a fair

enough limit would be to consider all proper motions as trustworthy which are greater than five times their probable error. In this case a star 3 times observed by Bradley in declination would usually be considered as in motion in either direction if the difference between Bradley and a thoroughly good modern determination was 4″ or more. And intermediate authorities would usually be found sufficient to confirm the motion. At the present time Piazzi and Groombridge, if errors of reduction are detected, are also old enough to give many accurate proper motions; and the best of the work done before 1850 is so much more precise that a good many stars not previously observed can be employed by careful re-determination. The least square combination of all, if proper weights are used, and systematic corrections applied, is still better.

The end to be attained is to thoroughly test the law of average distance, in inverse proportion to proper motions, down to the smallest certain values of the latter element. If we can do that, we can fairly assert that we know something about the average distance of a good many of the stars.

THE ANDROMEDES.*

J. MACLAIR BORASTON.

Though much disappointed by cloudy sky off the Azores obscuring the Leonids on the 13-14th November, the magnificent view of the Andromedes obtained last evening (23-24th November) more than made good the loss.

The observations were made on board the steamer "Don" in longitude 72° W., and latitude 17° N., south of Hayti, and consequently $4^h\ 48^m$ behind Greenwich mean time.

The radiant point was for a large portion of the six hours of observation so well elevated that the best position for watching the short-track and stationary meteors in order to fix it was found to be upon one's back.

Observation was commenced at 7 P. M. local time $= 11^h\ 48^m$ G. M. T., and a continuous watch kept up till $1^h\ 0^m$ A. M. 24th November $= 5^h\ 48^m$ G. M. T.

The great elevation of the radiant point, combined with a cloudless tropical sky, the absence of moonlight, and the unobstructed view of the complete hemisphere, afforded the *ne plus ultra* of astronomical requirement.

* Communicated by the author.

The intersection of some 70 short-track meteors about the radiant point, together with four coincident stationary ones, fixed the latter at R. A. 28° + 36°, about a fourth of the way from 56 Andromedæ towards β Trianguli. It has been determined in ignorance of any recorded radiant; in fact the shower had been by some means entered for the 29th November, and was only heralded by its own appearance.

Counts were taken at intervals in all parts of the heavens for areas of 60° = $\frac{1}{6}$ of the visible hemisphere, and for a duration of 5 minutes each. From these counts which were remarkably equal at all times and in all parts of the heavens, 18 meteors per minute come out as the average per area. As the shower was proceeding with undiminished energy after 6 hours of observation, the total number during these six hours may be set down at 108 per minute for the entire hemisphere, which gives 6,480 per hour, and a grand total of 38,880. This is certainly a minimum, for many of the faint, rapid meteors must have escaped notice, a safe inference from the number only just caught before extinction.

The heavens were alive in all parts, and every variety of meteor present, from the trackless stationary ones in the radiant-point to the the luminous pear-shaped 'drops' at the horizon, whose tracks often extended from 20° to 30° in length, and remained visible for roughly ten seconds after extinction of the meteor itself.

The shower must have extended into the opposite hemisphere, for when the radiant point occupied the zenith, the meteors ran down to the horizon; and when, after some hours it had declined appreciably westward, they still fell little short of it on the eastern horizon.

Several faint, swift, long-track meteors traversed the radial paths of the Andromedes proper, sometimes absolutely tangential to them, and, without exception (so far as could be observed) well removed from the radiant point. In fact they generally cut at about a right angle the paths of the slow, long, orange-track meteors occurring at about 50°-90° from the radiant point from which they were further differentiated by their swift motion, dull tracks and absence of anything like a visible head.

A further observation at 4:00 A. M. = 8^h 48^m G. M. T., showed the shower still active on that side of the heavens where the radiant point lay, though unfortunately cloud prevented systematic observation. Supposing the shower to have maintained its original activity, this would yield a total little short of 60,000 meteors for the hemisphere.

XUM

Why should these meteors appear so much brighter at a distance from the radiant point than in its vicinity? As the latter was near the zenith throughout observation, absorption would operate less effectually for meteors occurring there than for those at the horizon; add to which the fact that the tracks are seen more or less end-on, and one would expect that the compression of the light into a smaller area would render them more brilliant. This was unequivocally *not* the case, and instances of conformity rare. Short, sharp, dull tracks were the rule about the radiant, long slowly-developed brilliant yellow-to-red tracks as the hor izon was approached. The solution may be that the former class are of small mass and are promptly disintegrated in the higher strata of the atmosphere, consequently suffering little displacement from the radiant-point. The enfeebled resistance of the atmosphere at the higher levels would also account for their rapid motion and retention of the original direction of approach, whilst the small quantity of matter and rarity of surrounding atmosphere might be expected to yield the dull tracks observed.

On the other hand, supposing the long luminous meteors projected to the horizon to be of large mass, their apparent deviation from the original line of approach might be due to their having on that account entered the lower atmospheric strata, and the increased density of the latter would tend to retard their motion, and to set up more active combustion. But as the greater combustion is balanced by a larger supply of material, the tracks are not only brilliant, but long. The theory would seem to be further borne out by the insignificant or invisible head of the meteors in the neighborhood of the radiant, whilst those distant from it have generally large heads.

The memory of the 1892 Andromedes will remain long with me. The sight was one of the grandest I ever beheld: the perfect sky setting off the glories of Taurus, Orion, Canis, Argo, and other gems in the great belt, itself crossed in the zenith by the Galaxy, full of light; the symmetry in the development of the meteor tracks consequent upon the location of the center of radiation directly overhead; the multiplicity of motion and the underlying unity of principle,—all tended at once to stimulate and satisfy the mind.

JAMAICA, 25th November, 1892.

THE STAR OF BETHLEHEM.*

J. G. PORTER.

The Star of Bethlehem most naturally presents a subject of absorbing interest to the devout scholar, for its certain identification with any astronomical phenomenon, the occurrence of which could be definitely calculated, would not only afford a strong confirmation of the historical accuracy of the early records of Christianity, but would also throw a flood of light on some still unsettled questions of chronology. So much has been written on the subject that there would seem to be little left to say. In fact, in THE SIDEREAL MESSENGER for September, 1887, there is a full statement by the editor of what is known concerning the history of that memorable star. The results of the careful study made by the author of that article may be summed up as follows: "Of the Star of Bethlehem astronomy claims to have no knowledge. The latest study of the Christian astronomer leads to the belief that the wonderful star-like appearance at the birth of Christ was a phenomenon wholly miraculous."

With this conclusion I heartily agree; and the subject might well have been allowed to slumber for a time, but that no less an authority than Professor John N. Stockwell in a recent number of the Astronomical Journal again revives the planetary conjunction theory of Kepler, and proceeds to discuss it in a most interesting and able manner. He attempts to show that "the Bible narrative concerning the star in the east is better satisfied by a conjunction of Venus and Jupiter than by any of the conjunctions computed by Kepler." The conjunction here referred to, took place according to Prof. Stockwell's computation May 8, B. C. 6, and the planets were very close together, being about half a degree apart. Of course, they would present a most striking appearance in the morning sky, rising a couple of hours before the sun. In conclusion he says: "This close conjunction of Venus and Jupiter—a happy combination—the symbols of love and beauty associated with dignity and power—was a fitting announcement of the birth of a Prince who was to bring peace on earth and good will towards men, and is perhaps the strongest corroboration of the truth of the Biblical narrative concerning the origin of the Christian dispensation that has yet been found, having a purely scientific basis."

It seems almost a pity to criticise a theory which accords so

* Communicated by the author.

well with the desires of the devout mind, but I can not bring myself to regard this explanation of the phenomenon as at all satisfying the plain requirements of the Scripture history. In the first place, the wise men came from the east to Jerusalem, that is, in a general westerly direction. Prof. Stockwell assumes that the declaration, "we have seen his star in the east," refers to the location of the star and not to that of the observers. But if they saw the star in the east, why were they led to go westward in search of the Prince whom the star announced? It seems far more natural to suppose that the star which appeared to them in their native east guided them towards the land of Palestine, and must therefore have been in the western sky. In the next place, this assumption is rendered still more probable by the latter part of the Bible narrative which Prof. Stockwell fails either to quote or to explain. When they left Jerusalem "the star which they saw in the east went before them till it came and stood over where the young child was." At the time of the conjunction in question Venus had passed her western elongation and was approaching the sun. During the time occupied by the journey of the wise men, not only would the planets have separated in the sky, but Venus would be farther east and would only be visible for a short time before sunrise, and hence could not possibly have appeared to go before them from Jerusalem to Bethlehem, a direction nearly south. Nor does it seem to me that any heavenly body would meet the required conditions, for the Magi were perfectly familiar with the effects of diurnal motion, and even though the star might happen to stand over Bethlehem at the time of their arrival, they would know as well as we that it was purely accidental, and that a little earlier or later it would occupy a different position in the heavens. Here then seems to be an instance where we can not eliminate the miraculous from the Bible account, but must conclude that the Star of Bethlehem, like the Herald Angel, was a messenger directly from the realm of the supernatural.

Cincinnati Observatory, Dec. 5, 1892.

THE SOLAR CORONA OF APRIL, 1893.*

J. M. SCHAEBERLE.

Nearly three years ago I advanced a theory of the Solar Corona which practically accounts for the coronal forms observed.

* Communicated by the author.

With this theory as a basis I now give a general sketch of the Corona as it should appear at the next eclipse of the Sun (April, 1893) (Plate II) to those observing parties favored with the clearest skies and the best photographic outfits.

As I have had no occasion to change my views as to the essential structure of the Corona, it is not necessary to enter into a detailed explanation of the sketch, as the whole subject has been quite fully treated in the published memoir on "*A Mechanical Theory of the Solar Corona*," which forms part of the *Lick Observatory Report* on the Solar Eclipse of December 1889.

While it is evidently impossible to predict minor features of coronal structure caused by abnormal solar activity in special regions, *the fundamental features of a normal or typical corona should be recognized in every eclipse observed under favorable circumstances.* In the eclipse of April, 1893, the axis of the inner corona should be inclined towards the west.

The trumpet-shape outlines of the wings forming the outer corona should be recognized if the atmospheric conditions and the photographic manipulations are first class; if this particular feature is not shown, a most serious objection can be raised against the Mechanical Theory of the Corona.

Mt. Hamilton, Nov. 25, 1892.

THE PROPER MOTION AND SPECTRA OF STARS.*

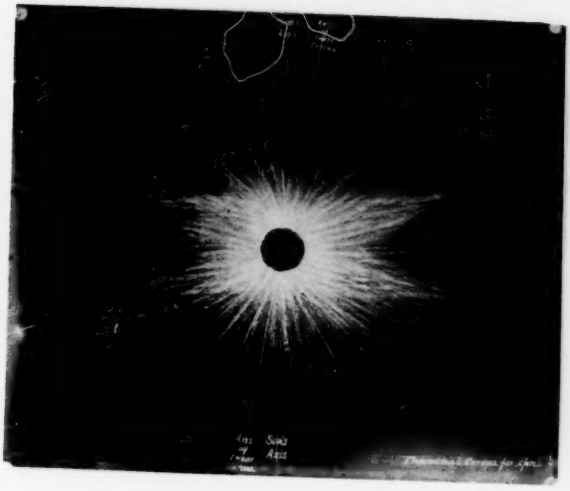
W. H. S. MONCK.

I have just completed an examination of the Pulkowa Catalogue on the same principles which I adopted in the case of the Fundamental Catalogue of Auwers. The figures given below may not be perfectly accurate but are substantially correct. The number of stars which I was able to identify both with the Harvard photometry and Draper Catalogue is about 1,600. As before I compared the motions N.P.D. only. I reduced these motions to what I previously referred to as the standard, viz., what they would be if the star was brought near enough to appear one magnitude brighter than the first (or say than Altair).

The average standard motion of the stars in this catalogue is at least 0″.265, that for Auwers' Catalogue being 0″.225. Both averages were found by ascertaining the point where the number of stars with greater and less proper motion became equal. The

* Communicated by the author.

PLATE II.



difference is evidently due to the smaller magnitude of the stars in the Pulkowa Catalogue which contains very few stars brighter than the fourth magnitude. It contains however, more than 400 stars of between the fourth and the fifth magnitudes, and these gave almost exactly the same standard motion as those of the same magnitude in Auwers' Catalogue, viz., about 0″.220. But upwards of 1,000 stars whose magnitudes ranged between the 5th and 6th gave an average standard motion of about 0″.275 The stars between the 6th and 7th magnitudes gave a still higher result but they were comparatively few in number and probably selected in many cases on account of their large proper motion. To ascertain whether the increase was continuous I tried the stars from magnitudes 4 to 4.5, and from magnitude 5.0 to 5.5 separately. The result was that the former gave an average standard motion of about 0″.200 and the latter of 0″.250. Whatever the cause may be the increase would, therefore, appear to be progressive for the two magnitudes from 4 to 6. The most probable cause is I think, loss of light in traversing space, owing to which as the distance of a star increases, the apparent magnitude diminishes in a more rapid ratio than that of the inverse square of the distance. But errors of observation and computation must be considerably reduced before we can draw any such inference with safety.

Comparing the spectra of the stars there were some remarkable changes chiefly arising from the notation of the Draper Catalogue. The distinctions drawn in that catalogue are too numerous to be carried out in the case of faint stars; and accordingly we learn from the introduction that "nearly all the fainter stars have been classed as A, E, or H, the additional lines, if present in the spectra, not being detected in the photograph owing to small dispersion." This will account for why the stars of the types B, G, I, K and M with which I have to deal are less numerous than in Auwers' Catalogue, being largely absorbed by the classes A and H. The spectrum F, however, occurs more frequently than E in the catalogue with which I am dealing. Owing to the increased standard motion of the fainter stars the figures arrived at for B, I, K and M may be too low (the G's are not numerous enough to draw any inference). The stars of class B however which number 41 exhibit the same extremely small proper motion as those in Auwers' Catalogue. The average standard motion determined in the same way as before is only 0″.100, or taken arithmetically about 0″.113. This is less than one-half of the average for stars with the spectrum A, (I have in all cases discarded the notes of interrogation in the Draper Catalogue.

The standard motions for stars of different spectra will, I think, be sufficiently indicated by the following table:

Kind of Spectrum.	No. of Stars.	No. with Standard motion of 1″ and upwards.	Per cent.	No. with Standard motion of 0″.5 and upwards.	Per cent.
A	775	53	6.84	149	19.23
B	41	0	0	0	0
E	51	23	45.10	26	50.98
F	203	74	36.45	117	57.64
H	357	54	15.13	128	35.85
I	86	15	17.70	32	37.21
K	46	7	15.21	13	28.26
M	38	1	2.63	12	31.58
Sirian *i.e.* A + B	816	53	6.49	149	18.26
Capellan *i.e.* E + F	254	97	38.19	143	56.30
Arcturian *i.e.* H + I + K	489	76	15.54	173	35.38

It thus appears that if all the stars were removed in such a manner as to appear to us of equal brightness, the Arcturian stars would have much more proper motion than the Sirian and the Capellan stars would have much more proper motion than the Arcturian. But when we are dealing with classes of stars instead of individual stars, there is good reason to suppose that their real motions are not on the average very different: in which case, if we take a Sirian, an Arcturian and a Capellan star of the same magnitnde, the former will be (on the average) the most distant and the latter the least distant, the Arcturian star occupying an intermediate position. Further, on the assumption of equal masses, the Sirian stars are the most brilliant and the Capellan stars are the dullest. The Arcturians and probably those with spectra of the third type (M) again hold the middle place. An Arcturian star is thus pretty plainly not a cooled-down Capellan. On the contrary, a Capellan star is probably a cooled-down Arcturian. The difference between the spectra A and B is somewhat similar to that between F and K or M, and in both cases the star with the greater number of lines in its spectrum appears to be the most brilliant. Cooling apparently leads to the disappearance of some lines and the narrowing of others—probably by the condensation of the absorbing vapors or their sinking beneath the photosphere.

We are not, as yet, I think, in a position to make accurate numerical computations on the subject nor have I leisure (even if I possessed the requisite mathematical skill) to make them. But a rough estimate of the relative brightness and nearness of the different classes of stars can be made wtihout difficulty. Comparing the relative brightness of the various binary stars in Mr. Gore's Catalogue, I find for the mean of the Sirians 14.00 and for that of the Capellans 2.10. These means were determined in

the manner already indicated. Now, assuming equal masses and densities, a star with the latter relative brightness should be brought 2.58 times nearer to us in order to appear of the same photometric magnitude with the other. I find that the average standard motion of the Sirian stars (spectrum A) in the Pulkova Catalogue is about 0.225″ and that of the Capellans (spectra E and F) is about 0.675″, the ratio being thus nearly 3 to 1. Assuming the real velocities to be equal, a Capellan star is thus, on the average, about 3 times as near to us as a Sirian star of the same magnitude. This agrees as well with the former result as could have been expected, and I think we shall not be far astray in concluding that, assuming the masses and distances to be equal, a Sirian star will appear at least two magnitudes brighter than a Capellan. Arcturian stars apparently occupy a position about half-way between. It is, no doubt, possible to invent other explanations of both series of facts. The larger proper motions of the Capellan stars may result from greater actual velocity in space or from the Sirian stars generally having a motion in space in better agreement with that of the Sun than the Capellans. The phenomena of binary stars may be explained by assuming that the Capellan stars are, on the average, of much larger mass than the Sirians, for large mass would reduce the proportional amount of illuminated surface and accelerate the revolution of the system. But we must adopt different explanations in the two cases and neither explanation rests upon a basis of observed facts. I therefore prefer the explanation which depends on the relative brightness or dullness of the illuminated surfaces—a brightness or dullness which we might naturally expect to find associated with the nature of the spectrum.

It is perhaps too soon to place the various kinds of spectra enumerated in the *Draper Catalogue* in order of greater or less illumination of surface, but I think the following arrangement will be found not far from the truth (the brightest being placed first) B, A, M, K, I, H, G, E, F.

TWO LARGE TELESCOPES.

A. A. COMMON.

Of the propriety of the appeal which Professor Pickering* makes there can be no doubt. It is very rarely that one can be made on

* Referring to Professor E. C. Pickering's circular concerning a large southern telescope.

such absolutely good grounds as this rests upon. From such an instrument in such a climate, under such admirable direction, most valuable and interesting results may with certainty be looked for—results of great importance to the astronomer, and which will be a source of great gratification to the donor of such a happily favored telescope. I sincerely hope that Professor Pickering will be successful in his appeal to his fellow countrymen.

With regard to the Paris telescope, the large size of the projected telescope over anything yet done makes the question of construction much more interesting. The largest silver-on-glass mirror yet made is my own 5-ft. From this to 10-ft. is a great step; from a focal length of 27 feet to 140 is a great leap. It brings us face to face with enormous difficulties, not perhaps insuperable if met in the proper way, but which may very easily become so.

I propose to briefly consider some of these and make a suggestion as to the best way to deal with them. Taking it for granted that the telescope, if properly made, will give results in light grasping power and definition in proportion to its size when compared with smaller instruments, and leaving out of consideration entirely the question of the suitability of the neighborhood of a large city as the site of a big telescope, with the remark that while I admit that the climate may not be the best possible, I should expect to gain in any given place by increasing the size and power of the telescope used whatever might be the advantages elsewhere.

As far as can be gathered from the English newspapers, the projected telescope is to have an aperture of about 10 feet and a focal length of about 140 feet—truly a gigantic instrument! Nothing has been said definitely about the style of mounting, but it is clearly meant that many observers shall be permitted to use the telescope. This last condition is of vital importance and affects the question greatly, for if the right kind of mounting is used to gain this end the whole thing becomes a feasible matter.

If it is intended, as I gather from what appears in this morning's '*Standard*,' to mount the telescope as an equatorial, with a cupola in the usual style, then I have no hesitation in saying that however well such an arrangement might do for one observer doing delicate astronomical work, it would be entirely unsuitable for giving many observers an opportunity of seeing any celestial object; to do this properly it will be necessary to resort to some modification of the altazimuth mounting, with the eye-piece com-

ing through the trunnions on which the tube of the telescope rests.

The unsuitability of the ordinary form of equatorial mounting becomes apparent when we remember that in order to render the eye-piece available for any position slightly off the meridian the upper part must be rotated, and this in such a large instrument would have to be frequently done as the telescope moved in right ascension; then the observer would have to be carried round at an irregular rate at a height of some 150 feet on some sort of stage, that while safe enough for one or two skilful observers could never be used by the world at large.

By adopting some form of the altazimuth mountings already so well known, with suitable modifications, all these difficulties could be overcome and many advantages gained.

The best use to put such an enormous telescope as that already mentioned would probably be to devote it to a general survey of the most important objects; for this purpose its great focal length and light-grasping power would be very valuable, with an altazimuth mounting and a fairly approximate movement in the two planes an object might be kept in the field well enough for continuous eye-work, though not, perhaps, accurately enough for very delicate measurements.

Even if something more than the parallactic movement of the equatorial had to be given up, the great gain that results from the altazimuth form of mounting as regards the difficulty of properly and effectually providing for the comfort and safety of the observer would more than compensate for it.

Sir William Herschel's 4-foot telescope was mounted in a very effectual manner too well known to make a description necessary; it has served for a model of several other reflectors which have done admirable work, as, for instance, the telescope mounted on this plan used by Sir John Herschel in his survey of the southern heavens.

The observer, however, is in the open air and at a considerable height when the telescope is pointed to the zenith. The tube of the telescope is necessarily a closed one, and the whole of the mounting is exposed to the wind and the weather. This form of mounting is very well suited for making sweeps of a degree or two in altitude, allowing the objects to come into the field of view for observation without movement of the telescope in azimuth; but it does not lend itself to the continuous observation of an object, nor is the position of the observer a very good one.

The plan used by Lord Rosse in mounting the 6-foot telescope

XUM

restrained the movement in azimuth to a comparatively short distance on each side of the meridian. The arrangements for the observer are slightly better for continuous work on an object within the range of the telescope in right ascension, enabling the study of nebulæ to be carried on in a better way than the mounting of Sir William Herschel's telescope permitted.

Mr. Lassell's four-foot telescope was mounted equatorially; but an inspection of the drawing of it and the observing tower is enough to show that the limit of size had almost been reached for that plan—a remark that also applies to the 4-foot reflector at the Paris Observatory. The earlier telescopes made by Sir William Herschel and, I believe, one made by Sir Isaac Newton, were mounted in a way that kept the eye-end at a fixed height. Miss Caroline Herschel's comet-sweeper was mounted in this way; but instead of moving the whole of the frame-work carrying the telescope in azimuth, Miss Herschel's telescope and the arrangements supporting it in altitude moved round on a central pivot. I do not know who was the maker of this particular form of mounting; it is certainly a most admirable form for the purpose for which it was made.

This plan of having the centre of motion in altitude close to the eye-end renders the position of the observer invariable as regards his height from the ground; his movement in following the telescope in azimuth is determined by the radius of the eye-end sweep which in cases under consideration would be about half the focal length of the telescope, a very small matter with a small telescope.

The largest telescope I know of mounted on this plan is that made by Dr. Draper, and so well described in his work on the construction of a 15½-inch silver-on-glass telescope, published by the Smithsonian Institution. Here we have a frame-work roughly in the form of a square, with the sides equal in length to the telescope; at one upper corner of the square the telescope-tube is swung in trunnions, one of which, being hollow, allows the light from the mirror to come to a focus just outside the trunnion—the telescope-tube being counterpoised by weights working at the end of bars supported at the diagonally opposite corner of the square to that where the eye-piece is situated, and connected to the mirror-end of the tube by wire ropes in such a way that their action is exactly equal and opposite to the weight of the end of the tube under varying angles, thus permitting the mirror-end of the tube to be raised or lowered while the eye-end remains at the same height.

XUM

In the case of Draper's telescope, the square frame-work carrying the tube and counterpoise weights was supported on a central pivot, and so the whole could be moved round as required. This, with the required inclination of the telescope-tube, allowed the telescope to be pointed to any celestial object without altering the height of the eye-piece, exactly as in Miss Herschel's telescope.

The observer was provided with a movable platform, which was quite independent of the framework carrying the telescope and could be moved to follow the eye-end of the telescope as required. The same part of the mirror is always uppermost in this form, and that makes the edge support much more easy than in the case of an equatorial, where the mirror may have any part of the edge uppermost.

There are many points about this form of mounting that are very good; one of the most important perhaps is the absence of heavy and costly constructional work. A very large mounting could be made very cheaply, using ordinary wrought-iron lattice-work girders and covering with thin sheet-iron—much the best material for surrounding a reflecting telescope. If it were decided to mount a reflector of the size given, I do not know any form that might be exactly copied so well as the mounting made by Dr. Draper. There is nothing impossible; but the large movement of the eye-end would be a source of inconvenience, as the platform would have to have a motion of varying amount to keep the observer within reach. In order to get rid of this trouble the important modification I would propose is to shift the pivot, which, as we know, is central in Dr. Draper's mounting, to a point exactly under the trunnions, balancing the frame-work by counter-poise weights. This could be very easily done by having a large *caisson* under, floating in water—the exact movement being kept correct by a strong central pin. We would have in this arrangement a frame-work similar to that of Dr. Draper, but turning on a pin or centre under the trunnions instead of under the centre of frame-work; the sweep of the eye-end would then be reduced from about 70 ft. (that is, about ½ the focal length) to about 7 ft. (that is, ½ the diameter of the tube *plus* a little for the projection of the trunnions). This frame-work with an open lattice-work tube with counterpoise arrangement would form the telescope proper, in place of a tube two lattice-girders on edge braced together at the top and bottom would connect the mirror and the trunnions, about the trunnions and for a little distance above and below there might be a tube connected by some flexi-

ble material to the portion of the frame-work near the trunnions, and the whole of the rest of the frame-work might then be covered in so as to form a large dark chamber in which the mirror would be free to work under the best conditions as regards freedom from currents of air; this would also form the best kind of work-shop in which the mirror could be made, by having the machine for working it just under the end of tube when vertical, so that it could readily be taken off machine and attached to tube or taken off for silvering.

With such a great amount of surface the effect of the wind might be injurious as regards definition, and it might be best to have, covering the whole of what we might call the mounting proper, another frame-work running on outer rails and covered over so as to protect the mounting within. This outer frame-work would then surround the mounting, being made large enough to allow it to rotate in azimuth some 30°, so that the outer frame-work would only require movement at intervals of two or more hours. At the upper portion, where the tube of the telescope would project, the outer frame-work would of course be cut away to allow the telescope to move without touching it—a platform being built to come up close to the trunnion forming the eye-end and forming part of a chamber which could be of any desired size on the outer frame-work, access by any suitable means being provided on this outer frame-work. The movement of the trunnion with the eye-end being in a circle of about 7 ft. radius, would not be very great during the movement of the telescope during the two or more hours that it could be used without the movement of the outer frame-work.

This arrangement of outer and inner frame-work becomes very large, but it would answer admirably; nearly one-half becomes useless as regards sheltering the telescope and might be to a large extent dispensed with, the only objection being the great power the wind would have upon such a large surface rotating in one corner. This could be largely prevented by making the sides with considerable slope and having an arrangement for anchoring to the rails if necessary. As regards the actual amount of material required in the construction of the covering, this would be largely reduced, The inner chamber formed by covering the inner frame-work and forming the telescope might be obtained, not separately as proposed, but by using the outer frame-work and cover. We should then have a telescope of the following description:—An open frame-work in general construction very similar to that designed by Dr. Draper in all the important parts,

XUM

excepting that the centre of rotation would be under the trunnions instead of under the centre of frame-work; this would have to be balanced, but with a large floating circular vessel there would not be any difficulty in doing that. This frame-work telescope would be covered by a strong outer frame-work of the shape on plan of a triangle, the apex being the centre of rotation of the inner frame and the base the line that the outer portion of this frame-work would sweep—say an angle of about 40° or 45°, so that the inner frame-work would be free to sweep through this angle without coming in contact with the outer one. The junction of the tube of the telescope near the trunnions with the outer frame could be made air-tight by any flexible material that would not communicate the vibrations of the outer frame-work to the telescope. The platform for the observer and his dark chamber, etc., could be of almost any size.

The mounting here suggested would enable a constant stream of visitors, if needed, to go up and down the outer frame-work without in any way interfering with the telescope: it would permit the mirrors to work under the best conditions, and, above all, it would allow the observer to work under the most favorable conditions, not only as regards his personal safety and comfort, but as regards the absence of that constant movement that is needed with the equatorial. In fact, a little consideration will show that, apart from the question of making a show telescope, this arrangement is really the best that could be used for a large reflector, which might be called an exploring telescope, and be used for many purposes and in many situations where the ordinary mounting could not be taken, owing to difficulties of transport.

As regards the mirror, although the increase from 5 to 10 feet is great, there ought not to be any great difficulty in casting and properly annealing the glass; that done, the rest is only a matter of time, care, and patience. There is not the least difficulty beyond the making of the glass that need cause any doubt as to the ultimate success. From the thickness found to be perfectly sufficient in the 5-ft. mirror, a thickness of from 10 to 12 inches for a 10-ft., would be ample.

Even if the idea of making this large telescope be abandoned, I hope that a similar one may be made on the lines I have suggested, as for a given amount of outlay it seems likely to give the best results, particularly in that general exploring work for which it is so peculiarly suited.—*Observatory*, November and December, 1892.

XUM

THE HOLMES' COMET.

So many questions have been asked and so much popular interest awakened about the new comet, during the last two months, that it seems best to give a brief statement relating to its characteristics and its history since the time of its discovery. This new comet was first seen Nov. 6, 1892, by Mr. Edwin Holmes, an amateur astronomer, residing in London, England. On the evening of that day, Mr. Holmes was trying to observe through a hazy atmosphere, and as a test object, he chose the small *Comes* to μ Andromedæ. While moving his small telescope upon the object above named, he saw, in its finder, a nebulous object, which he soon satisfied himself was a new comet of considerable size and brightness. As quoted by the *Observatory* for December, he said at the time: "This is coming end-on and will be a big fellow, and I must get a position before I leave it if possible." Mr. Holmes wrote at once concerning his discovery to Mr. Maunder, Mr. Maw and Mr. Kidd of Bramley. He determined the place of the comet at the time of discovery as immediately preceding Σ 72, and, by the aid of a Slade micrometer, motion was easily detected. The measure of the diameter of the nebulosity was five minutes of arc very closely and the comet's position was as follows: In right ascension $0^h\ 46.8^m$; in declination $+\ 38°\ 32'$.

The new comet was seen on the evening of the 7th of November with the naked eye, by the English observers, Mr. Kidd and Mr. Barttell of Bramley. It was again seen on the 14th at $10^h\ 45^m$ by Mr. Holmes and decided changes in appearance reported. The nucleus was much less distinct than one week before, and much less bright, the boundary of the nebulosity less well defined and less perfectly circular. The intrinsic brightness was also less and the diameter was largely increased. Mr. Holmes' estimate of the size of the comet's head as seen in the field of the micrometer was, at that time, from 8′ to 9′ in diameter.

November 11, when Mr. Holmes reported his discovery to the *English Mechanic*, he said: "I think it (the comet) must have appeared suddenly, for I observed that region, October 25, and observed nothing special." As the position was in the direction from which Biela's comet might approach the Earth, Dr. Berberich of Berlin, a rapid and experienced computer, immediately called attention to this fact and some astronomers assumed the new comet to be Biela's and calculated the distance it should be from us, and the time it would cross the Earth's path. The re-

sults obtained from these computations indicated that the time the comet would cross the Earth's path was only a few hours from that when the Earth would surely pass the same point. Such statements in the hands of newspaper reporters quickly gained very wide circulation, producing the impression that there would be a collision between the Earth and the comet on or about the evening of Sunday, November 27, 1892. As a result something of a "comet scare" was experienced in some parts of this country that reminded one a little of the woeful events predicted for the comet of 1843 in the early part of that year. It must be confessed that there was some ground for apprehension in the public mind, from statements reported to have been made by some prominent astronomers. But when it was learned very soon after that their conclusions were based on incorrect or erroneous observations, none could be more ready or anxious to correct wrong impressions than were these same astronomers themselves. But, as error often outruns the truth for the time being, so in this case, not a few simple folk were doomed to the woes of fearful anticipation up to, and including, that Sunday night, that we suppose were only faintly represented by the political cartoonists in the newspapers of that date, who were trying to picture the just and speedy retribution of wicked opposing politicians. The moral of this is that astronomers should be more careful in the future for the sake of the reputation of the science, to say nothing of the harm of involving the innocent in jeopardy. To remind politicians incidentally of the possibility of an awful future for them may not be blameworthy. On the other hand it is a well-known fact that not a few persons did watch the sky faithfully on the Sunday night before mentioned in the expectation of seeing the comet and probably something of the startling phenomena predicted.

Another most interesting fact appearing nearly coincident with the Holmes' comet was the brilliant meteoric shower of Wednesday evening, Nov. 23, 1892. The display was remarkable in many parts of the United States and in some localities of Europe already heard from. The radiant point was in the constellation of Andromeda, and the rapidity with which the meteors fell is shown by statements from a few observers at different places mentioned below:

At Northfield, Minnesota, one person counted, on the average, 15 or 20 per minute. The display was from 7 o'clock P. M. until midnight.

From Princeton Professor Young reported that the meteors

were already numerous at 7 o'clock, and from 7:30 to 12:30 when it clouded, they were falling at the rate of 100 in four or five minutes, and that within the range of vision of the place, the total number falling must have been at least 30,000 during five hours.

At Palo Alto, California, Leland Stanford University, Professor W. J. Hussey reported that a single observer could see 50 or 60 fairly bright meteors every five minutes corresponding to a daily rate of from 400,000,000 to 500,000,000 on the hemisphere of the Earth towards the radiant.

Professor Hussey fixed the radiant very closely, he thinks, at $\alpha = 1^h\ 39^m$; $\delta = +\ 42°$.

Professor Young determined the radiant roughly at 8:30, as being a circular area of about 4° in diameter whose center was $\alpha = 1^h\ 20^m$; $\delta = +\ 41°\ 30'$. At 10 o'clock it seemed to be more definitely limited and several nearly stationary meteors fixed it at $\alpha = 1^h\ 30^m$; $\delta = 40°\ 30'$. At 11 o'clock it was again determined at $\alpha = 1^h\ 40^m$; $\delta = +\ 40°$. From these observations a change in the position of the radiant seems possible if not probable, especially when compared with the results obtained by Denza referred to by Professor Young in his note on the meteoric shower (p. 943, Dec. 1892, A. A.-P.). He there suggests the important query whether a recession of the node can be accounted for by perturbations since the year 1885.

Holmes' comet was barely visible to the naked eye on the evening of this display and was about 10° west and 4° south of the radiant.

It is, so far as known, the general belief of astronomers that this grand display of Nov. 23 was none other than that of the Bielid meteoric stream which has been one of special interest for twenty years past. As Professor Young says, if this swarm is moving in the path of the Biela comet, then its period of revolution must be 7 years instead of the 6.6 years which was the period of the Biela comet. Either the swarm is a new one or the orbit of the old one is changed, or possibly still the dismembered fragments of the old Biela comet have more divergent paths for separate swarms of meteors than is known from existing records of this Biela family. These recent phenomena of the meteors will certainly interest the students of this branch of astronomy, and we shall hear from them further, doubtless at an early date. It is now certainly known that the new comet, is in no way at all connected with the late meteoric shower, except accidentally to appear nearly at the same time in very nearly the same place in

the sky. Knowledge of the elements of the orbit of the comet was determined by computers less quickly than usual in the case of new comets because in obtaining an approximate parabolic orbit unusual difficulties were met by experienced computers in satisfying the middle place. It therefore became necessary to wait for observations at wider intervals, and then only elliptical elements would answer the degree of approximation sought for reasonable verification. Several such sets of elements have been computed by European and American computers, two of which are given below. A study of the elements of this comet's orbit will reveal some most interesting features.

The comet appears to belong to Jupiter's numerous family of comets having the aphelion point of its orbit just inside the orbit of that planet at a distance from the Sun represented 5, or five times the mean radius of the Earth's orbit. Its perihelion is at a distance of 2.17 with a longitude of 349°. The eccentricity of the orbit is remarkably small—only 0.39. There is no other known comet orbit that is so nearly circular. The aphelion distance being small this comet ought to be followed throughout its orbit by the larger telescopes, certainly. If this be true the perturbations by Jupiter, as suggested by Schulhof, may be studied with special advantage.

It is also a noteworthy fact that the comet's orbit lies wholly within the minor planet belt, as is shown by its small inclination to the ecliptic. Its motion is direct, and its orbit one of extremely small eccentricity and unusually short period of revolution around the Sun.

Two sets of elements show these facts, and indicate other points for further study. Those by Rev. George M. Searle published Nov. 21 are:

$$\left.\begin{aligned} T &= \text{Oct. } 11.9802 \text{ G. M. T.} \\ \omega &= 42^\circ\ 19'\ 02'' \\ \Omega &= 325\ \ 41\ \ 16 \\ i &= 19\ \ 16\ \ 43 \end{aligned}\right\} 1892.0$$

$$\log a = 0.525258$$
$$\log e = 9.504648$$
$$\text{Period} = 2241 \text{ days.}$$

Those by A. Berberich of Berlin published Nov. 27 are:

$$\left.\begin{aligned} \omega &= 18^\circ\ 12'\ 14.8'' \\ \Omega &= 331\ \ 4\ \ 23.2 \\ i &= 20\ \ 39\ \ 38.8 \end{aligned}\right\} 1892.0$$

$$T = 1892, \text{June } 20.7357, \text{ B. M. T.}$$
$$\varphi = 23\ \ 9\ \ 0.6$$
$$\mu = 523''.335$$
$$\log a = 0.554151$$

Under date of Dec. 3, 1892, Mr. Searle reports that he has computed a set of new elements for the comet from observations of Nov. 8, 16, and 24, the last of which was later found to be inaccurate, so the new elements have not been published. These elements indicate a period of 6¾ years and a time of perihelion passage in the month of August, 1892.

Elsewhere in this issue will be found a detailed description of the observations and drawings of this comet made at Goodsell Observatory of Northfield, Minn. Plate I shows some of the sketches from Dr. Wilson's note-book.

SOME RECENT MARKINGS ON JUPITER.*

MARY W. WHITNEY, VASSAR COLLEGE OBSERVATORY.

During the past October and November, observations upon surface features of Jupiter have been made at our Observatory with the twelve inch equatorial. The atmospheric conditions have been on several evenings remarkably good and we have secured better views of Jupiter than I have ever before seen. A similar series of observations was carried on a year ago. I send some of our best views, as drawn by my assistant, Miss Wagner.

The red spot has suffered a striking change since last year. It has grown larger, much fainter and more diffused. It is too faint to show decisive color, at least to my eye. In good seeing, the following edge was comparatively well defined, but the preceding edge was never seen in clear outline, Fig. 5. It would seem by its present appearance to be breaking up. Its upper and lower edges generally seemed to lie against the neighboring belts, though a few of our sketches show a clear space between it and the southern belt, in which it lies. At times it has struck us that this line of separation was more plainly discerned when the spot was coming on or passing off than when near the central meridian.

The great southern belt has changed little in its general contour since last fall. The slope in which the red spot lies preserves about the same angle. We have observed various white spots within this belt, generally elongated in form and very elusive. They have been far more difficult to hold than any other of the white spots we have seen. Three of our drawings of views not including the red spot show an almost continuous light streak running longitudinally through the belt. This was seen only at

* Communicated by the author.

PLATE III.

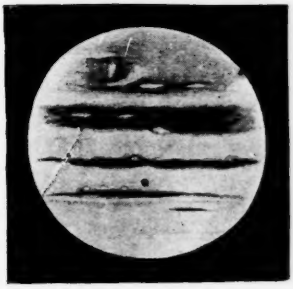


FIG. 1.

FIG. 2.

FIG. 3.

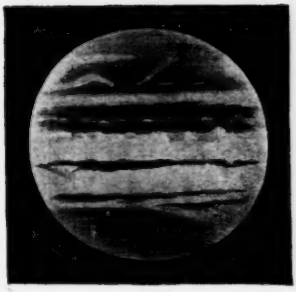


FIG. 4.

FIG. 5.

FIG. 6.

XUM

times and under the best conditions. On Nov. 11th a similar rift was noted in another part of the belt, at the point where it again widens, after the narrowing which accompanies and precedes the red spot. Perhaps this may presage a separation of the southern belt into two. We have noticed also that the northern border of this belt just following the red spot sloped southward, out of parallelism with the north belt. The concavity shown in Fig. 5 with the dark spots preceding and following was noted on other dates, Oct. 28 and Nov. 11th.

On several evenings we have obtained very fine views of this belt, giving the effect of cumulus clouds with beautiful light brown shadings. On Oct. 26, when the seeing was exceptionally good, we called these shadings pink.

The Northern belt has been conspicuously darker than any other throughout our observations. It has shown considerable variation, presenting dark spots and breaks more or less extensive. On Nov. 11th, Fig. 6, it was entirely broken asunder at one point. We have noted white spots above and below this belt, but at no times within it.

The southern cap, as we call it, frequently looks like two or more belts, the lowest of which lies against the red spot and shades a little lighter than the great southern belt. This bordering belt, however, does not extend around the planet. We have seen it only on the side with the red spot. This cap has contained white spaces more irregular in form than any other we have observed. The figures represent some of our clearest views of these markings. They have been quite persistent and have predominated on the side opposite the red spot, *i. e.*, on the side where the lower edge of the cap has not shown the belt-like appearance. Might not these facts, if further substantiated, have some bearing on the effect of the great red spot on the cloud masses lying south of it?

The northern cap has been more uniformly shaded than the southern. It has shown irregularities, as in Fig. 4, but no defined spots.

The Northern white belt has been brighter than the others. We have not been able to detect any shadings upon it.

XUM

THE PROBABLE ORIGIN OF HOLMES' COMET.*

SEVERINUS J. CORRIGAN.

The comet discovered by Holmes at London, Eng., on Nov. 6, 1892, and which has attracted universal attention of late, has presented features so anomalous that it may be regarded as a body unique among the members, permanent or temporary, of the "solar system," and as one inviting the special investigation of astronomers, particularly as to its origin.

In the first place, while its slow apparent motion has so far prevented the computation of very accurate elements of its orbit, those that have been determined have shown clearly enough that it is a body which was at time of discovery, and is now, receding from both the Sun and the Earth, and that it was nearest to both long before Nov. 6, 1892; therefore it should have been considerably brighter, and larger in apparent dimensions some time before the date upon it was found by Holmes.

Now it is most remarkable, considering the assiduity and care with which the heavens are continually scanned, through powerful telescopes, by astronomers specially engaged in the search for comets, that this body which was quite visible to the naked eye shortly after the time of discovery, should have escaped detection long before it was found by Holmes, who has said that he had shortly before examined that region of the heavens in which he subsequently found the comet, and had observed nothing extraordinary therein. This sudden appearance in so prominent a shape is the first noteworthy peculiarity of this body.

Another anomaly is that while this comet was receding from both the Earth and the Sun, its apparent diameter increased in a most remarkably rapid manner, and that, while the increase was taking place, the brightness decreased.

The object of this article is to suggest a possible, and I may say a *very probable* cause for all these peculiarities. I believe, and I think this belief may be substantiated by subsequent observation and computation, that Holmes' comet had its origin in a collision of some two members (known or unknown) of the large group of asteroids which revolve around the Sun in orbits between those of Mars and Jupiter.

Under this hypothesis only can, I think, the remarkably sudden appearance of so bright and large a body be rationally explained.

* Communicated by the author.

The result of such a collision, even at a quite moderate relative linear velocity, would be, obviously to heat the colliding bodies so that they would be disintegrated, and dissipated in the gaseous form, or as vapors and mixed dust and gases. Spectroscopic observations of this body seem to indicate that it shines principally, if not wholly by reflected light, and that therefore it must be composed of solid particles, probably greatly comminuted. The diameter of the vaporous globe resulting from such a collision would rapidly increase, just as would that of a puff of smoke following the explosion of powder, and the augmentation of the diameter, and therefore of the apparent surface, would be accompanied by a diminution of brightness, the decrease being inversely as the square of the increase of diameter, according to well-known optical principles, the actual number of light-giving particles remaining constant while the area over which they are spread increases as the square of the diameter. The elliptic elements determined by Rev. Mr. Searle and by Dr. Kreutz might well belong to one of the members of the asteroid group, and I think that they are the approximate elements of a resultant body due to the collision of two asteroids on, or shortly before Nov. 6, 1892, when Holmes discovered the comet.

The eccentricity is somewhat greater than the greatest appertaining to any of the asteroids, but this greater eccentricity in the orbit of a body resultant upon such a collision is perfectly normal, the arrest of orbital motion of the components tending to cause the resultant body to fall more directly toward the Sun and therefore to describe an orbit around that body more eccentric than either of the orbits of the original bodies of which the resultant is composed.

I hope to be able to determine soon which members of the group of asteroids are the components of this comet, that is, if such components were known members of the asteroid system.

ST. PAUL, Minn., Dec. 24, 1892.

It is an interesting fact that several astronomers independent of each other have suggested the hypothesis of collision for the origin of the Holmes' comet. That such an origin, within the asteroid belt, should have been thought of is singular; if it should prove to be the true explanation of the origin, it will be considered by the friends of the meteoritic hypothesis as an important fact favoring Mr. Lockyer's theory. The strongest point of evidence suggesting this origin is the spectrum of the comet which shows that it shines by reflected light only, so far as known by observation up to the present time. If the comet continues bright enough this feature will be studied further diligently.

XUM

HOW THE EARTH IS MEASURED. *

PROFESSOR J. HOWARD GORE.

One of the most primitive ideas regarding the Earth represented it as an immense plain, or flat island, surrounded on all sides by an interminable ocean. This ocean in the minds of the Greeks was only a river, called Okeanos, and into this the Sun made each night a plunge, to arise in the morning on the opposite side of the Earth. At the extremities and borders were placed the "fortunate isles," or imaginary regions inhabited by giants, pigmies, and such mythical creatures as a vivid imagination could call into being. But when men began to have experience of the sea by navigation, the horizon always observed as circular led to the notion that the ocean was bounded, and the whole Earth came to be represented as a circle, beneath which were roots reaching downward without end.

The cooling of the Sun from his daily bath demanded some change in the material into which he plunged. And as he could not go down on one side and come up on the other without making the subterranean journey, some provision had to be make for his passage. It was easy to imagine a tunnel through which he could pass, but as soon as the progressive and retrograde movements in his places of setting and rising were recognized, it was necessary that the support of the Earth be honeycombed with passages. The Buddhist priests declared that the Sun passed between the pillars which supported the Earth. And no sooner did they find this theory acceptable than they applied it to their ends. For, said they, these columns are sustained by virtue of the sacrifices which were made to the Gods, and any indifference on the part of the worshippers might cause a collapse of the Earth.

The ancient Greenlanders affirmed that the Earth is upheld by pillars which are so consumed by time that they crack, thus quaking the Earth; and were it not for the incantations of the magicians, the Earth would long since have broken down. Thus we see a myth reaching

> "From Greenland's icy mountains
> To India's coral strand."

The Hindoos held the Earth to be hemispherical, and to be like a boat turned upside down upon the heads of four elephants,

* Extract from "The Journal of the Franklin Institute," Nov. 1892.

which stood on the back of an immense tortoise. This support, like a superficial answer, was sufficient until some curious questioner insisted upon knowing upon what the tortoise rested. The answer, upon the universal ocean, was soon proffered and gladly accepted, until the application of the further test, on what does the ocean stand? The ultimatum was then reached; the theory so boldly advanced and so ingeniously sustained needed a foundation principle; this it received in a shape that stilled further doubts and strengthened the whole superstructure: What supports the ocean? Why, it goes all the way to the bottom. This form of reply did not disappear with those who first made it, nor has it found a place in earth theories alone. Almost every science has advanced its line of interrogation points until a final all-sufficient answer is given, or an accepted axiom quoted.

Anaximander, a philosopher of the sixth century before Christ represented the Earth as a cylinder, the upper face only being inhabited. By some process now not known he computed its proportions, and gave as the result that its height was one-third of its diameter, and that it floated freely in the center of the celestial vault. The doctrine of "sufficient reason" prevailed then, or was invented to fit this particular case, because when asked why this cylinder did not tip over, he replied that in the absence of a reason why it should tip in any one direction rather than in another, it did not tip at all, hence remaining in this state of helpless indecision. A fellow-philosopher, recognizing the importance of air in the economy of nature, supported the cylindrical Earth of Anaximander on compressed air, which, owing to the vague and apparently imponderable character of air, did not suggest the need of a resting place for this air cushion.

Aristotle relied more upon fancy than upon fact, and deduced conclusions from logic and the nature of things rather than from observation. He reasoned from what he deemed natural to what must be or is. In answer to the question, Is the Earth at rest? he replied, "The Earth is in repose, because we see it to be so and because it is necessary that it should be, since repose is natural to the Earth." He also affirmed that a circle is a perfect line, being uninterrupted and without ends; and, therefore, the stars, created by God to endure forever, must have an eternal motion, and being perfect creations they must move in the perfect line—the circle. The heavens, also, possessing this divine attribute of perpetuity, must move in a circle. Then, as a grand climax, he asserted that since in every revolving circle there is a

point of absolute repose, the centre, the Earth, being at rest, must occupy this central point.

Strabo, the geographer, who made the first century of the present era illustrious by his maps, declared the Earth to be spherical, for in all his investigations and study regarding the travels of sailors and explorers he found no mention of the end of the Earth. To him it appeared central and motionless, and in his consistent ignorance he unyieldingly affirmed that the entire habitable globe was represented on his maps, and was in shape like a cloak 8,000 miles long and 3,600 miles in width, the greater dimension being from east to west; hence our term longitude for degrees counted in that direction.

Bede, known as the Venerable, who lived in the eighth century, regarded the Earth as formed upon the model of an egg. Being an element, it is placed in the middle of the universe as the yolk is in the middle of the egg; around it is the water, like the white surrounding the yolk; outside that is the air, like the membrane of the egg; and around all is the fire, which closes it in as does the shell. The Earth, being thus in the centre, receives every weight upon itself; and though by its nature it is cold and dry in its different parts, it acquires, accidentally, different qualities; for the portion which is exposed to the torrid action of the air is burned by the Sun, and is uninhabitable; its two extremities are too cold to be occupied, but the portion that lies in the temperate region is habitable. The ocean, which surrounds it by its waves as far as the horizon, divides it into two parts, the upper of which is inhabited by us, while the lower is inhabited by our antipodes; although not one of them can come to us, nor one of us go to them.

As in other theories, a support was needed. To meet this requirement Edrisi, an Arabian geographer, broached the idea that the egg-like Earth floats in the great ocean as in a basin.

Although we are told that Pythagoras and Thales taught that the Earth was spherical, we see that their teaching was without avail on this point for nine centuries, while the shape of the Earth was the play of many foolish fancies. Bede again rounded it off and gave to it the egg shape which it retained in the minds of men for 1,000 years. Many of these theories were so erroneous that they were in nowise links in a great chain which could bind all peoples into unanimity of belief. But while many were beating time without marching, others were making progress along hopeful lines.

XUM

Now that the development of ideas had carried men far enough to accept a spherical globe, it was only natural that speculations were rife as to its size, and it was equally natural that some one should come forward with a method for determining this magnitude; and while this method might in itself be inaccurate or unsatisfactory, yet it would serve as a quickening force in the elaboration of better and still better plans.

Before attempting to measure the entire Earth it was necessary that considerable success should have been met with in measuring limited portions of its surface. Just when this art was first practiced is hard to ascertain; probably when Joshua was sent to spy out the land, he had in view quantity as well as quality.

We are told by Herodotus that the credit of discovering geometry belongs to the Egyptians, who found need of its principles in the restoration of those boundaries of fields which were obliterated by the overflow of the Nile. He also gives us the method of procedure when the river god consumed portions of a man's landed possessions. "If the river carried away any portion of a man's lot, he appeared before the king and related what had happened, upon which the king sent persons to examine and determine by measurement the exact extent of the loss; and thenceforth only such rent was demanded of him as was proportionate to the reduced size of his land. From this practice, I think, geometry first became known in Egypt, whence it passed into Greece."

With the acceptance of the belief that the Earth was spherical came the notion that by finding the length of 1° on the Earth's surface a simple multiplication by 360 would give the entire circumference, and this circumference being the same for the same sphere the measurement of 1° would suffice for the determination of the size of the Earth.

Following out this idea, Eratosthenes communicated in 276 B. C. a value for the Earth's circumference, followed in 135 B. C. by Posidonius, as results of approximate measures and erroneous observations.

Just here we must take a long step chronologically but not geographically. The exact sciences ceased to be cultivated in Greece and Egypt. They slumbered for centuries and awakened in Arabia. When the Arabians adopted the Mohammedan religion they became ambitious for mastery not alone in the field of battle, but in the arts and sciences. They embraced, extended and utilized the knowledge they found during their occupation of Egypt. They preserved trigonometry from oblivion and handed

it down to us in its present shape, while to them we are indebted for the beginning and early development of practical astronomy. The Arabians reached their zenith under Caliph Almamon. He was not only a scholar, but a patron of the sciences, and assembled about him the most learned men of that period, among whom were Acaresimi, Alfraganus and Albategni.

This wise caliph was the next to make a contribution to the world's knowledge of the size of the Earth. In 819 he imposed upon his astronomers the task of measuring a meridional arc on the plain of Singar by the Arabian Sea. They divided themselves into two parties, and starting from a given point, one party went north, measuring with wooden rods as they went, the other due south, likewise measuring as they went. Each party continued, the former until they reached a point where the altitude of the pole was just 1° higher than it was at the starting point, while the other did not stop until they found a place where the altitude had decreased by 1°. Thus we see both groups had gone just a degree. The northward party had measured fifty-six miles, the southward, fifty-six and two-thirds miles.

It is said that they repeated their measurements and obtained identically the same results. However, others affirm that, appreciating the impracticability of the successful discharge of their duties, they adopted the value given by Ptolemy, which is perhaps about the mean of the two just given.

The method here described possessed geodetic features far in advance of those employed by the Greek mathematicians, but we have no information regarding the way in which the altitude of the pole was determined. From a lack of exact data as to the length of their unit, we are unable to form any opinion as to the accuracy of their result.

For 700 years speculation slumbered, and investigation was ignored. A cloud of ignorance hung over the world like a pall, and the attainments of the earlier inhabitants did not even remain as a shadowy dream. The discovery of mathematical writings left in Spanish cloisters by their Moorish invaders awakened some interest in the study of the exact sciences, and from the oblivion of the dark ages arose, Phœnix-like, the genius of that grander culture then begun, now unfinished.

In the opinions of men the Earth was a plane, and again there was that painful, tedious uplifting of the benighted people to the realms of truth. Fortunately, the demonstrations were not left to the theorist alone; the science of navigation had by this time enabled men to venture beyond their littoral thorough-

fares, and Magellan, circumnavigating the world in his three-years' voyage, placed beyond the confines of hypothesis the globular form of the Earth.

In the ignorance of methods of determining differences of longitude, it was impossible to ascertain the amplitude of an arc extending east and west. The determination of latitudes was an early art, but the measuring of an arc of meridian whose amplitude was, centuries ago, approximately ascertainable was limited to direct measurement.

Inasmuch as the task of finding a suitable stretch of country fulfilling the required conditions was difficult, the number of direct determinations were few, being restricted to Fernel, 1525, and Norwood, 1633.

THE PHYSICAL APPEARANCE OF HOLMES' COMET.

H. C. WILSON.

The following notes are compiled from the notes and sketches in my observing book. The observations were made with the 16-inch equatorial of Goodsell Observatory, power 150, and the 5-inch finder, power 30.

Nov. 11, 11^h—The comet is very bright, nearly round and nearly uniform in brightness, except that following the nucleus, in position angle 120°, there is a bright miniature tail as indicated in the sketch (Plate I, Fig. 1). Notwithstanding the brightness of the comet, the faint stars of 11 and 12 magnitude show vividly through it. The diameter of the nebulosity is about 6.5′.

Nov. 15, 9^h—A sketch indicates that the comet was a little larger but fainter than on Nov. 11. The lower right side of the head is extended slightly more than the upper portion.

Nov. 18, 10^h—Careful micrometer measures give the following results:

Position angle of the miniature tail following the nucleus 113.6°.

Diameter of the head at right angles to this tail and through the nucleus 11.7′.

Distance from nucleus to edge of nebulosity on the side opposite the little tail 4.3′.

The sketch indicates that the nebulosity extended about 7′ on the following side.

XUM

Nov. 22, 9h—The bright portion following the nucleus is much enlarged. Position angle 122.9°. Length 15′. Radius of head in opposite direction 5′. Cross-section through nucleus at right angles to tail 13′. In all of the above observations the nucleus was quite definite and of about the tenth magnitude, with little condensation about it except on the following side.

Dec. 10, 8h—The comet is very faint. The nucleus is hazy, about 12 magnitude with condensation of nebulosity about 1′ diameter surrounding it.

With the 16-inch it was quite difficult to find the boundaries of the faint nebulosity of the comet. It was about 20′ in width across the nucleus and a degree or more in length. The sketch (Plate I, Fig. 2) gives a fair idea of its shape and extent. The nebulosity was better seen in the five-inch finder than in the 16-inch. The comet was picked up before the observation with a pair of opera-glasses.

Dec. 16, 7h—Comet very faint but large, slight condensation about the nucleus.

Dec. 23, 8h—Comet very faint but easily seen in the finder (five-inch); about 15′ in diameter. With this instrument the nucleus could not be seen. In the 16-inch but little could be seen but the condensation about the nucleus, 1′ or less in diameter. When the light was turned off for some time I could trace the nebulosity to about 5′ on the preceding side of the nucleus and farther on the following side.

From these notes and others which have been printed in this journal it will be seen that the behavior of this comet has been quite different from that of others in receding from the Sun. It has expanded very greatly in size, and its brightness has diminished out of all proportion to the law of the inverse squares of the distances from the Sun and Earth. Its spectrum on Nov. 18 did not show the ordinary bands of a comet spectrum, but was continuous through a considerable portion of the green. This seems to indicate that this comet does not emit light of its own but shines by reflected sunlight only. The diminution of brightness is quite consistent with the enormous expansion of the nebulous matter. The apparent decrease in size during the last observations appears to be simply because the nebulosity has become too diffuse to be longer visible.

On the whole the appearance has been that of a mass of steam such as might result from an explosion, gradually diffusing and becoming invisible because of its tenuity. Judging from the faintness of the nucleus at our last observation, Dec. 23, it seems hardly possible that the comet can be followed much longer, even with the great telescopes.

XUM

ASTRO-PHYSICS.

SUN-SPOTS AND MAGNETIC PERTURBATIONS IN 1892.*

A. RICCO.

The United States Naval Observatory has sent to the Catania Observatory a reproduction of the curves of the photo-magnetographs which give the magnetic perturbations of 1892. I have deduced from it the epoch of maximum by taking into account the greatest deviation of the declination (D.) and the greatest variations of the horizontal component (H. F.) and vertical component (V. F.) of the intensity of terrestrial magnetism. But the determination of the time of this maximum is not very certain, since the perturbations consist of very extensive and very complicated oscillations, and, morever, the maxima of D. H. F., and V. F. do not always coincide. I have confined myself to giving the times of these maxima, and I have compared them with the calculated times of the passage of the principal spot at its least distance from the center of the solar disc, *i. e.*, over the central meridian. I have reduced the time of the 75th meridian W. of Greenwich, which has been adopted at the Washington Observatory, to Catania time, which I employ in my daily observations of solar phenomena.

Following is a brief description of the spots at the time of their passage over the central meridian of the Sun, and the corresponding magnetic perturbations; the oscillations are referred to the means and expressed in minutes for D. and in ten-thousandths of the C. G. S. unit for H. F. and V. F.

JANUARY 4, 2^h P M. Large spot, very active; there are other spots, but they are smaller and more distant from the center of the solar disc. JANUARY 6, 4^h A. M. Great oscillation of D. from $-48'$ to $+14'$; corresponding oscillations of H. F. from $+3$ to -16, and also of V. F., but in the opposite direction, from $+22$ to -13.

JANUARY 28, 3^h P. M. Large spot, and a few other small ones very distant from the center. JANUARY 28, NOON. Brief perturbations. Rapid oscillation of D. from $+23'$ to $-5'$, strong oscillations of H. F. from $+6$ to -7, depression of V. F. to -13.

FEBRUARY 2 TO 4. No important spot on the solar disc. FEBRUARY 2 TO 4. Four or five perturbations, not strong in D. feeble in H. F. and almost absent in V. F.

* Communicated by the author.

FEBRUARY 12, 4^h A. M. Extraordinarily large spot, very active, with red flames in the nuclei; north of it is an important group of spots; near the east limb is another remarkable group. FEBRUARY 14, 1^h M. Extraordinary magnetic perturbation, lasting nearly 36^h; continual and strong oscillations of D. from + 28′ to — 62′, enormous vibrations of H. F. and V. F., both traces leaving the field; aurora borealis, and extraordinary electric earth-currents (according to Mr. Preece).

MARCH 1 TO 4. No spot near the center of the Sun; important group near the west limb. MARCH 1 TO 4. Six or seven perturbations, unimportant in D. feeble in H. F., very feeble in V. F.

MARCH 7. No spot near the center of the solar disc; the great spot of February has reappeared at the east limb. MARCH 7. Perturbations lasting for two days; sudden oscillation D. of from ± 28′ to + 20′; curious movement of H. F. from 1 to — 13.

MARCH 10, 2^h P. M. The great spot of February, reduced to smaller dimensions, is again at the central meridian; no other important spot near the center of the solar disc. MARCH 21, 11^h A. M. Very strong perturbation lasting 30^h, great oscillation of D. from + 44′ to — 9′; very strong decrease of H. F. from — 3 to — 17. V. F. not recorded.

APRIL 23, 8^h P. M. Active and important group of spots and pores; other equally important groups farther from the center.

APRIL 25, 11^h A. M. Steady increase of D. up to + 16′ and finally a fall to — 25′; remarkable oscillations of H. F. from + 7 to — 6 and of V. F. from — 6 to + 4.

APRIL 24, 4^h P. M. Active and important group; other groups farther from the center of the solar disc. APRIL 26, 1^h P. M. Strong perturbation lasting about twenty hours in continuation of the preceding; remarkable increase of D. from — 22′ to + 24′; great oscillations of H. F. between + 5 and — 20; very strong fall of V. F. from — 6 to — 24.

MAY 1 TO 2. No spot near the center of the solar disc; several groups near the limb. MAY 1 TO 2. Two or three remarkable perturbations of D. H. F. and V. F.

MAY 16, 5^h P. M. Very large spot, very complicated and exceedingly active, and other spots nearer the center of the solar disc. MAY 18, 6^h P. M. During 24^h great disturbance of D. between + 20′ and — 22′; strong and repeated oscillations of H. F. between — 20 and + 18 and of V. F. between — 24 and + 10.

The following table gives in an abridged form the numerical values deduced from the diagrams of the perturbations, and from calculation of the positions of the spots; the *deviations* are the

amplitudes of the oscillations near the *maxima* of the perturbations. The diameter of the spots is expressed in terrestrial diameters. The retardation of the perturbations after the time of passage of the principal spot at its least distance from the center of the solar disc is given by the difference in time, and also by the arc of heliographic longitude which the spot has traversed beyond the central meridian at the time of maximum magnetic perturbation.

Time of Passage over Cen. Meridian	Principal Sun-spots.	Diameter.	Heliographic Latitude.	Time of Maximum.	Magnetic Perturbations.	Deviations.			Retardation of the Perturbations	
						D.	H. F.	V. F.	In time.	In arc.
			°			′			h	°
Jan. 4, 2 P.M.	Very large	4	+ 20	Jan. 6, 4 A.M.	Very large	42	0.0013	0.0035	38	25
Jan. 28, 3 P.M.	Large	3	— 16	Jan. 29, noon	Large	28	13	13	21	12
Feb. 2 to 4	None			Feb. 2 to 4	Small					
Feb. 12, 4 A.M.	Extraordinary	11	— 30	Feb. 14, 1 A.M.	Extraordinary	90	∞	∞	45	25
Mar. 1 to 5	None			Mar. 1 to 5	Medium					
Mar. 7, 2 A.M.	None			Mar. 7, 2 A.M.	Large	48	14			
Mar. 10, 2 P.M.	Extraordinary	6	— 29	Mar. 12, 11 A.M.	Very large	53	20		45	25
Apr. 23, 8 P.M.	Large	2½	+ 11	Apr. 25, 11 P.M.	Large	41	13	10	51	28
Apr. 24, 4 P.M.	Large	3	+ 16	Apr. 26, 1 P.M.	Large	46	25	18	45	25
May 1 to 2	None			May 1 to 2	Medium					
May 16, 5 P.M.	Extraordinary	5	— 16	May 18, 6 P.M.	Extraordinary	42	18	34	49	27

The schematic figure represents in an approximate manner the position of the principal spots at the time of the corresponding maximum; the heliographic latitude of the center of the solar disc, amounting to $\pm$ 7° 15′, and the resulting perspective curvature of the parallels, have been neglected.

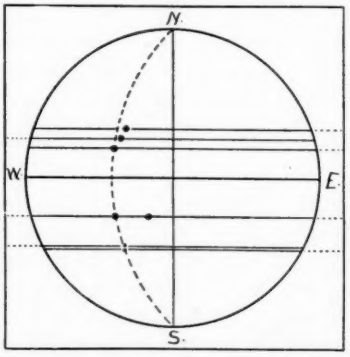
It follows that out of 11 periods of perturbed terrestrial magnetism 7 occurred after the epoch of the passage of the principal spot over the central meridian at its least distance from the center of the disc, and that all perturbations, extraordinary, very strong, strong, have in general followed the same passage of spots respectively extraordinary, very large, large. Medium and feeble perturbations are produced without the passage of spots; so that there is a certain proportionality between the two classes of phenomena. The great perturbation of March 7 was the only one not preceded by the passage of an important spot near the center of the solar disc.

These retardations (except that of January 29) are comprised between 38^h and 51^h; the mean is $45\frac{1}{2}^h$; and as the synodic rotation of Sun-spots has a duration of about $27d = 648^h$, it is evident

that this retardation is only about $\frac{1}{14}$, and the deviations from the mean which amount to as much as $7\frac{1}{2}^h$ are not at the most more than about $\frac{1}{100}$ of the time of this rotation period.

The figure shows the agreement of six cases, and evidently proves that it is not possible that this position of the principal spots (about 25° of heliographic longitude from the central meridian) can be the result of chance. It should also be added that two passages of the same extraordinary spot, in February and March, were followed after *the same retardation* by magnetic perturbations. At present it is impossible to explain the disaccord of the perturbation of January 29, which occurred only 21^h after the passage of the principal spot over the central meridian.

The retardation of $45\frac{1}{2}^h$ would indicate a velocity of propagation from the Sun to the Earth of about 913 kilometres per second for the action exercised by Sun-spots on terrestrial magnetism; this velocity would be more than 300 times less than that of light.



Positions of the Principal Spot on the Sun for Each Strong Magnetic Perturbation from January to May, 1892.

We certainly do not know whether the maximum of this action has its seat exactly in the nucleus of the principal spot of the group, as we have supposed and as seems probable; but in any case it seems very difficult to believe the seat of this action displaced more than twenty degrees of longitude behind the spots, where ordinarily only the secondary phenomena of pores and faculæ occur, these seeming by preference to *follow* the principal spot of the group. The retardation cannot, therefore, be explained in this manner.

It is known, especially as the result of the long and important

investigations of M. Wolf of Zurich, that there is a perfect agreement between the mean variations of magnetic decliantion and the mean number of Sun-spots, and M. Garibaldi of Genoa has demonstrated that this agreement is verified even in the details of the variations. Father Secchi and M. Tacchini also admitted long ago a relation of spots and solar prominences with magnetic perturbations and auroras.

Lastly, observation has taught us that in Sun-spots there are great movements and contacts of various vapors at different temperatures, which might produce electric phenomena of great intensity. Moreover, it is known as the result of spectroscopic observation that many lines, especially those of iron, are widened in spots, which indicates a very great density, or at least a special condition of this metal in spots; and this may explain their magnetic action.

The ignorance in which we find ourselves as to the propagation of these electric or magnetic actions in a vacuum, or more exactly in interplanetary space, is not a sufficient reason for denying their existence.

It is my intention to pursue this inquiry for preceding years in order to see whether these relations between Sun-spots and magnetic perturbations always occur in the same manner.

OSSERVATORIO DI CATANIA, October, 1892.

ON AN ENORMOUS PROMINENCE, OBSERVED AT THE HAYNALD OBSERVATORY OCT. 3, 1892.*

J. FENYI.

On October 3, 2^h P. M. Kalocsa M. T. (or Oct. 2, 19^h Washington M. T.) I observed on the eastern limb of the Sun a prominence of perhaps greater dimensions than any previously measured, even at the period of maximum solar activity.

The phenomenon extended over 30° on the Sun's limb, and attained a height of 8′ 51″, that is, 0.552 of the Sun's radius, or 51,600 geographical miles. The form of the gigantic prominence was sketched at the eye-piece between 1^h and 2^h, and is faithfully represented in the accompanying plate; it was composed of a number of fragments, some of which were very brilliant. The numbers represent the measured positions, counting from north through east. They give the heliographic position −13° 14′ to

* Communicated by the author.

-35° $22'$ on the eastern limb of the Sun. The vast dimensions caused some difficulty in measuring the height, because, as this could be done only by transits across the slit, it was not possible to find the right position of the slit, which should touch the limb of the Sun at a point directly below the top of the prominence. The value obtained in position 145° is, however, to be regarded as a minimum, an error in the position of the slit, in any case only causing the height to be too small. Besides the error can amount to a few seconds only. The height of the part floating above 151° could still be measured with a spider-line micrometer in a wide slit at 1^h. I then found $128''$ as the distance of the lower part from the limb of the Sun. The mass rose quickly or must have faded away partly, for the later tourists gave a height of $306''$ at 2^h 25^m. The six transits of the whole prominence immediately succeeding one another and lasting over a minute each, indicate a rapid rise of the top, giving a mean velocity of 36 km. per second; the real velocity, however, was probably greater, for at the same time the top was noted to be fading away.

At 2^h 55^m nothing remained of the higher parts. Displacements of spectral lines did not occur. No connection of this exceptional prominence with other solar phenomena has been noticed.

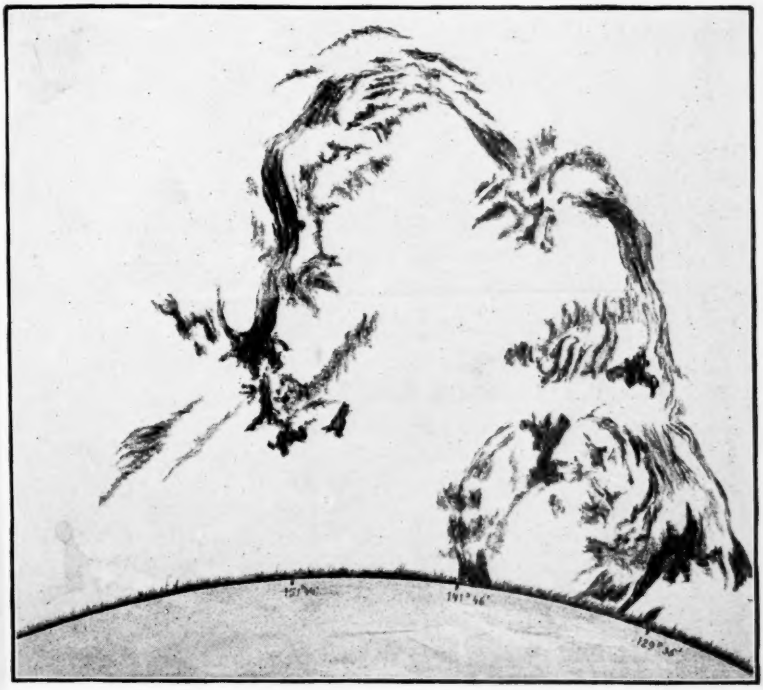
It should be noted that the phenomena of solar activity, so frequent in the first half of this year, have decreased since about the middle of June, spots as well as prominences being relatively quiet and of only small dimensions.

KALOCSA, Hungary, Oct. 10, 1892.

It may be of some interest to add that the prominence referred to in Herr Fényi's note was photographed at the Kenwood Observatory on Oct. 3 at 1^h 57^m and again at 2^h 5^m, Chicago, M. T., about 7^h later than the time of the Kalocsa observation. The form of the prominence in the photographs is quite similar to that shown in the plate, but the extent on the limb is apparently greater. The height is about $2'$. At the point where the base of the prominence rises from the Sun, and also where the fainter extremity descends to the surface, groups of faculæ are clearly shown.

G. E. H.

PLATE IV.



Prominence Observed at the Haynald Observatory,

October 3, 1892, 2^{h} P. M., Kalocsa M. T. Height, 8′ 51″.

XUM

RESUME OF SOLAR OBSERVATIONS MADE AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE DURING THE THIRD QUARTER OF 1892.*

P. TACCHINI.

The season has been favorable, and the series is nearly continuous. The following are the results:

1892.	No. of Days of Observation.	Relative Frequency of Spots.	Relative Frequency of Days without Spots.	Relative Size of Spots.	Relative Size of Faculæ.	No. of groups per Day.
July	32	24.32	0.00	153.1	80.309	4.77
August	30	21.20	0.00	123.83	57.17	6.50
September	27	19.22	0.00	72.82	86.40	5.37

The phenomenon of Sun-spots has thus continued with an intensity nearly as great as in the preceding quarter, although a slight progressive diminution is shown in the number of spots; the mean number of groups is also a little smaller. The considerable size of spots during the month of July, when the mean number of groups shows a secondary minimum, should be noticed; this is principally due to the large spot group which was at the center of the solar disc on July 10, and which occupied one-third of the radius of the disc; and the still larger group, which arrived at the central meridian on July 31, and extended over two-thirds of the radius; both these groups were visible to the naked eye. The presence of these groups, however, did not cause perturbations in our magnetic instruments, and the only important magnetic perturbation observed by us occurred on July 16. I therefore think that I have always been right in affirming that perturbations of terrestrial magnetism are in closer relation with the phenomena of the chromosphere and solar atmosphere, and especially with electrical solar phenomena, which we observe under the form of filamentous prominences and very rapid motions, than with spots. But to reach a conclusive demonstration continuous observation of the limb and the disc will be necessary, and I expect much from Professor Hale's beautiful photographic investigations.

For the prominences we have obtained the following results:

1892.	No. of Days of Observation.	Prominences. Mean Number.	Mean Height.	Mean Extent.
July	30	10.27	39″.2	1°.8
August	29	9.76	41 .6	2 .0
September	26	11.08	41 .8	2 .0

In the phenomenon of prominences we find a marked increase

* Communicated by the author.

XUM

both in number and height as compared with the preceding quarter; for the spots the reverse was the case. In a few instances prominences have been seen at a great elevation above the solar limb, as in the case of the cloud observed by me August 1, which rose to a height of 364″.

ROME, Italy, Nov. 5, 1892.

THE MODERN SPECTROSCOPE.*

IV.

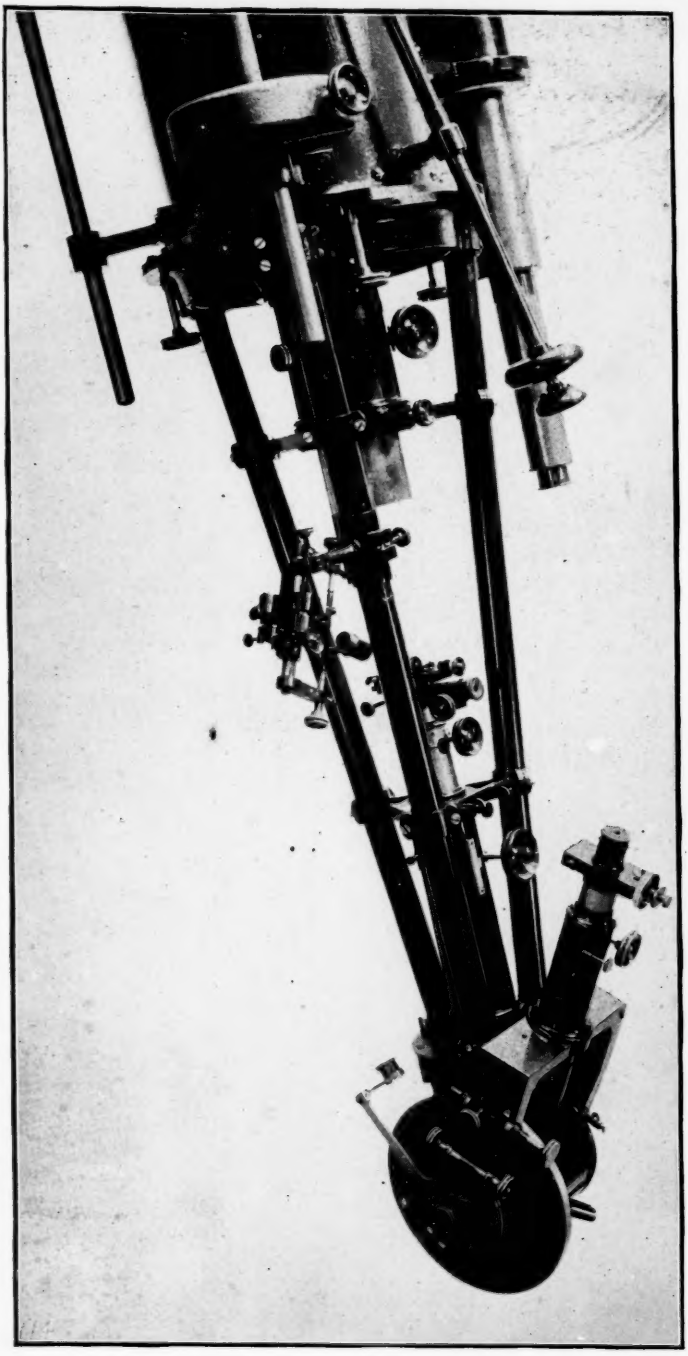
The Spectroscope of the Alleghany Observatory.

JAMES E. KEELER.

The spectroscope which is illustrated in the accompanying plates is the most important recent addition to the instrumental equipment of the Allegheny Observatory. Although not strictly a universal instrument, it is intended to be used for several different kinds of work, and to be efficient in all of them. In a previous article † I have stated the general principles which must be observed in constructing a spectroscope for any given purpose. It is not an easy task to design a spectroscope which shall satisfactorily meet a number of very different requirements, and in presenting the Allegheny spectroscope as one solution of this difficult problem, I wish to point out that some additions and conveniences, which might easily have been added, were rejected because it was thought that they might compromise the utility of the instrument in some one of its applications. After testing the spectroscope in both visual and photographic observations, although as yet only in a preliminary manner, there are very few changes that I should wish to make in the original design. The instrument is large and powerful enough to compare favorably with others of the highest class, designed for the same kinds of work, yet light enough to be readily mounted and dismounted, and to be carried by a telescope of moderate dimensions. It is convenient in use, and most important of all, it is very rigid, and capable of yielding results of extreme precision. The Observatory owes this splendid addition to its resources to Mrs. Wm. Thaw, of Pittsburgh, who generously supplied the funds for its construction without any limitations whatever. The spectroscope and all its accessories were made by Mr. J. A. Brashear. Hints for

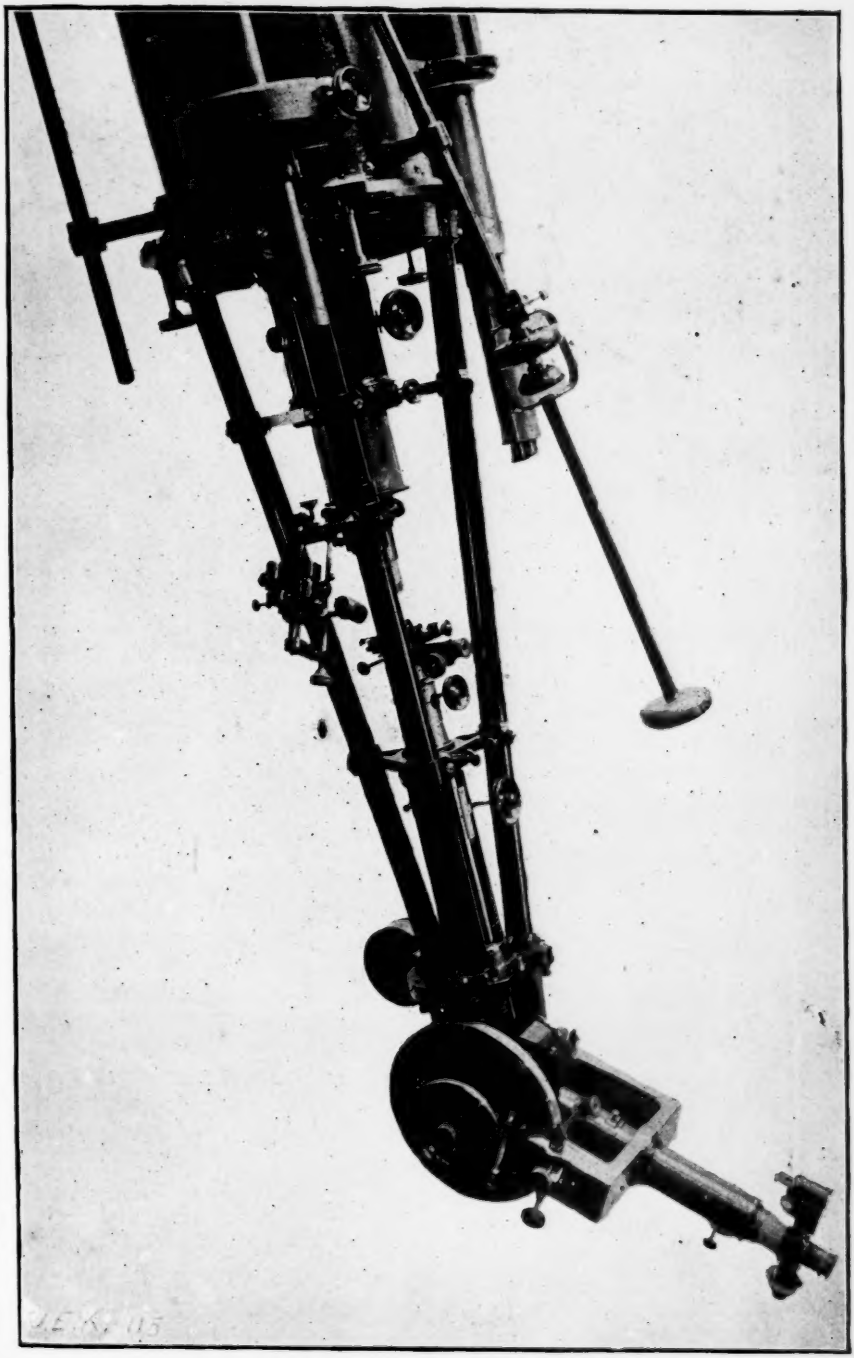
* Comunicated by the author.

† *Sidereal Messenger*, November, 1891.



The Allegheny Observatory Spectroscope.

1. Arrangement with Grating for Visual Observations.



The Allegheny Observatory Spectroscope.

3. Arrangement with Single Prism for Visual Observations.

XUM

the design were gathered from various sources,—from my previous experience with the Lick Observatory spectroscope, from Vogel's spectrograph and other modern instruments, and from some very excellent spectroscopes which had been previously designed and made by Mr. Brashear. The working drawings were made by Mr. George Klages, foreman of the mechanical department in Mr. Brashear's works, and to his suggestions many practical improvements of the details are due.

The old wooden tube of the thirteen-inch equatorial did not promise to afford a sufficiently secure support for the spectroscope, and for this and other reasons it was replaced by a new steel tube, fitted with a new eye-end, finder, and other appointments. The end plate of the new tube is a strong casting, with a flange two inches greater in diameter than the end of the tube. This flange carries the entire weight of the spectroscope. The end plate is secured by nine pairs of butting and clamping screws, by means of which the axis of the tail-piece or collimator axis of the spectroscope can be accurately directed to the center of the telescope objective. The end plate is also provided with a position circle divided to degrees.

The main frame of the spectroscope consists principally of two rings, one large and one small, connected by three 1¼ inch steel tubes. The upper and larger ring is 13 inches in diameter. It forms the principal support of the spectroscope, and is clamped to the flange of the end plate by three stout screws, which are arranged as clips. When these screws are loosened the spectroscope can be rotated around the axis of the telescope, and the reading of the circle on the end plate gives the position angle of the slit. On throwing out the clips, the spectroscope is detached from the telescope.

A secondary support, which greatly increases the rigidity of the instrument, is formed by a smaller ring which fits accurately a slightly conical bearing on the lower end of the tail-piece. After the three large clamps have been tightened, this ring is also clamped, by a screw which is shown in the plates.

The lower ring is 6 inches in diameter. Its outer face is flat and smooth, with a depression for centering the attachments which will be described below. The hole in its center just allows the passage of the lower end of the collimator. An additional support to the rod is a triangular brace which holds the upper end of the collimator case. The collimator case has no centering screws, as the adjustment of its axis is effected by means of the screws in the end plate of the telescope, in the manner already described.

XUM

In constructing the instrument, the whole eye-end of the telescope was placed in a lathe, the spectroscope frame was built upon it, and everything was turned up true in this position, this method of construction ensuring the perfect centering of all the parts.

The face of the lower ring is 2 feet 7 inches from the end plate of the telescope, and 14¼ inches from the focal plane of the objective.

The collimator slide has a range of 1.4 inches. The position of the collimator is given by a millimetre scale and index on the outside of the case, the motion being effected by a large focusing head. The collimator tube, and all the sliding tubes of the spectroscope are nickel-plated. Two clamps secure the collimator in any desired position. A visual and a photographic objective are provided, each having a focal length of 16 inches and an aperture of 1¼ inch. As the ratio of focal length to aperture of the 13-inch refractor is 14.10, the effective aperture of the spectroscope is 1.13 inch. A stop with an aperture of this size can be placed on the end of the collimator, to limit the emergent beam from the comparison apparatus.

The slit is quite similar to the slit of the Lick Observatory spectroscope,* although a few additions have been made. The jaws open symmetrically from the center by turning a screw with divided head, one division of which changes the slit width by 0.001 inch. By turning another small head, the length of the slit can be varied. A thin tongue of brass, which is fined down to a point at its extremity, can be slipped over the exact center of the slit, in order that the comparison spectrum may be photographed without encroaching on the previously exposed photograph of a star spectrum. The width of the tongue at its intersection with the slit can be varied by a small adjusting screw. Another small head throws the 60° comparison prism on or off the slit. The diagonal eye-piece for viewing the slit from behind has a rack and pinion movement, and it is made to slide very easily between stops. When the train of prisms shown in Plate VII is used, this eye-piece is not accessible in its usual position, and it can therefore be rotated 90° and clamped in the position shown in the plate.

The tubes containing the cylindrical lenses fit the ordinary eye-piece adapter, and are adjusted to the proper distance from the slit by means of the focusing screw of the main draw-tube.

The comparison apparatus is quite similar to the same attach-

* See Astronomy and Astro-Physics, February, 1892.

ment of the Lick Observatory spectroscope, except that, as none of the rods is in the prolongation of the slit, it is secured to the frame of the instrument in a somewhat different manner. It is arranged for both metallic points and spectrum tubes, and all necessary adjustments are provided. An image of the source of light is formed on the slit, after reflection by the prism, by a lens which has a greater angular aperture than the collimator. The comparison apparatus can be readily detached from the rod which holds it, and placed, if desired, above the spectroscope, with the tube or spark in the optical axis of the collimator. In my opinion the latter arrangement is not a desirable one, at least when the metallic spark is used.

The parts of the spectroscope so far described weigh 42 pounds. They are common to all the different arrangements of the instrument, three of which are represented in the plates. The desired arrangement for any kind of work is obtained, in the first place, by attaching to the face of the annular plate in which the frame of the spectroscope terminates, one or the other of two distinct pieces of apparatus, each of which is a complete spectroscope with the exception of a collimator; and in the second place, by using with either of these attachments either a visual telescope or a camera. The separate attachments I have called, for want of better names, the "grating head" and the "prism-train box," or "prism-box." Each has a strong circular base-plate, which fits the terminal plate of the spectroscope frame, the two plates being held firmly together by four stout screws. In order to facilitate the change of heads, the screw holes are slotted and counterbored, and the screws need never be entirely withdrawn. With this arrangement the exchange of heads is very easily effected.

The base plate of the grating head is cast in one piece with two strong, ribbed arms, which project from it about 5½ inches and carry the pivots of the observing telescope. The distance between the parallel inner faces of these arms is 4.4 inches. The cross-arm which carries the observing telescope is also strongly ribbed. On one side is the fixed graduated circle, 8 inches in diameter, the edge of which is divided on silver with a double set of graduations. The outer set shows the position of the observing telescope, the inner set the position of the grating or prism. The circle is fixed in such a position that the reading of the outer vernier is zero when the telescope is in line with the collimator; for any other position of the observing telescope the reading of this vernier gives directly the deviation of the observed ray. Both verniers read to 30″ with the aid of a small reading micro-

XUM

scope, or easily, by estimation, to 15″. In designing the instrument it was intended that the circle should serve mainly as a finder, the comparison apparatus and micrometer being relied upon for exact results by differential measurements. The cross-arm which carries the observing telescope is provided with a slow-motion screw and clamp.

Through the hollow pivot on the side toward the graduated circle passes the long spindle of the grating table, or circular brass plate on which the grating and prisms are mounted. The outer end of the spindle is fitted with a clamp, ratched wheel and tangent screw, all of which are well shown in the plates. Just below the grating table, the inner end of the spindle is encircled by a collar, which carries the tail-piece of the minimum deviation apparatus, and which is clamped to the spindle after the prism is set to the position of minimum deviation for any spectral line.

Each prism has its separate mounting, which is readily secured to the grating table. The grating is mounted in the usual manner, with all necessary adjustments.

Two loosely fitting, thin brass covers, one for the grating, and one for either prism, exclude all stray light in observing. One short piece of tube projects from the cover and receives the lower end of the collimator; another short tube is attached at one end to a thin plate, bent to the curve of the cylindrical side of the cover, and at the other to the end of the observing telescope, where it is held in position by a small clamp. The cover is prevented from falling off by a small screw pin, which passes axially through the pivot on the side opposite to the graduated circle, and enters a central hole in the top of the cover. No resistance is therefore opposed to the motion of the observing telescope.

When the grating is used, the minimum-deviation arms are removed; the observing telescope is turned toward the collimator until its cross-arm rests against two stops provided for the purpose, and then clamped. Different parts of the spectrum are brought into the field by rotating the grating. The angle between the axis of the collimator and observing telescope in this position is 30°, which is the smallest angle allowed by the construction of apparatus.

Both prisms have refracting angles of 60°. One is made of heavy flint, the other of light flint glass. The flat Rowland grating has 14,438 lines to the inch, the ruled surface measuring 1.3×1.8 inches.

The aperture of the observing telescope is 1.25 inch and its

focal length is 10 inches. All the objectives of the spectroscope are made of Jena glass, and have a considerably smaller chromatic aberration than the ordinary combination of crown and flint. The lenses are cemented with castor oil. For the sake of stiffness the tube of the observing telescope is quite large (1.85 in. diameter), and for the same reason and in order to make the instrument as compact as possible, the tube projects through the cross-arm into which it screws, the broad flange of its bearing being 3 inches from the object-glass end.

The micrometer has 50 threads to the inch. It carries a coarse and a fine wire, illuminated by a small electric lamp at one end. The lamp is enclosed in a small box or lantern, fitted with a revolving disc containing colored glasses, which can be removed from the micrometer when desired. The micrometer is divided on "zylonite" to 100 parts, whole revolutions being read on a dial outside the box. The draw-tube is graduated to millimetres, and provided with a focussing screw and clamp.

There are three achromatic eye-pieces, one having a power of 5.6, intended to give the maximum of brightness, one with power of 12.5 for general use, and one magnifying 25.0 diameters for solar and other work requiring a high power.

In observing with a prism, the observing telescope is counterpoised. The bearing of the counterpoise arm is independent of the pivot which is on the same side, in order to preserve the pivot from strain or unequal wear.

Plate V shows the spectroscope arranged for visual observations with the grating, and Plate VI, the arrangement when a prism is used. In the latter plate an extension rod is shown, clamped to the slow-motion screw which moves the telescope in declination. This screw is thus brought within easy reach of the observer at the eye-piece. The slow motion in right ascension is effected by means of cords. A triangular piece of sheet iron with a small central hole is supported by the three rods, just in front of the slit, to protect the instrument from the heat in observing the Sun.

The weight of the grating-head, without telescope or counterpoise, is 17 pounds.

The prism-train box is attached to the frame of the spectroscope in the same way as the grating head. It contains a train of three rather dense flint glass prisms, connected by an automatic minimum-deviation apparatus, the details of which were worked out by Mr. Klages. Considerable study has been given to this important part of the apparatus, particularly with a

XUM

view to securing the rigidity which is essential in photographic work with long exposures. The minimum deviation of the Hγ line for each of the 60° prisms is 60° 18′, or for the whole train, 180° 54′. Light corresponding to this line is therefore sent back nearly in the direction from which it came, a condition which allows a construction extremely favorable to rigidity. At the same time the movable prisms are an unfavorable condition. As I disliked extremely the idea of confining work to one part of the spectrum, it was necessary in adhering to the original plan, which allowed a considerable range of motion, to arrange the prisms in such a manner that no shifting of their positions could occur during a long exposure. The arrangement which was finally adopted as a probable solution of the difficulty is the following: each prism is mounted on a table with three feet, which rest on the flat face of one side of the prism-box. To these feet the link-work or gearing of the automatic minimum-deviation apparatus is attached, with a slight amount of play. Opposite the center of each prism, a clamp passes through the other side of the prism-box, by which the feet of the prism are pressed firmly against their support. Hence, when these clamps are tightened, the prisms are held, not by the link-work of the minimum deviation apparatus, but by the sides of the box, just as they would have to be held if they were fixed.

The observing (or photographic) telescope screws into a peculiarly shaped box, the faces of which are planed flat and truly parallel, and made as broad and long as possible. This box fits snugly and yet moves smoothly between the sides of the prism-box. Four clamps, two on each side, pass through curved guiding slots in the sides of the prism-box, and keep the observing telescope pointed in the direction of the emergent rays. The curvature of these slots was determined graphically. To this sliding box is attached the outer end of the minimum deviation train, which is of the geared form devised (I think) by Grubb. When all the clamps are tightened, the observing telescope and all the prisms are secured firmly to the sides of the prism-box. No slow motion is provided for the telescope with the train of prisms, as its position is not supposed to be frequently altered.

Whether this arrangement will give the desired rigidity with movable prisms, can probably be determined only by prolonged trial. I can only say that in a number of long-exposure photographs of planetary spectra, made with this apparatus, the lines are beautifully sharp, and show no traces of shifting of the prisms.

The camera, or photographic telescope, has an aperture of 1.25 inch, and a focal length of 16 inches. Both this, and the photographic collimator objective, are corrected for the Hγ line. The object-glass is adjustable by a focusing screw, the plate-holder remaining fixed. Its slide is provided with a scale, and a clamp not shown in the plate.

Two short rods extend from the frame of the spectroscope to a collar on the camera tube. When they are clamped to the latter the stiffness of the whole apparatus is greatly increased, as the slit and the camera are almost directly connected by a short brace. The range of the photographic telescope is from C to just below H.

The camera has two metallic plate-holders, for 2 in. $\times$ 3 in. dry plates, and a ground glass screen for approximate adjustment.

For exact determination of the photographic focus there is a separate attachment, consisting of metal plate, mounted in the same way as the ground glass, but having a central aperture, into which fits the high power eye-piece already mentioned. The inner face of the plate is made to occupy the exact position of the photographic plate when the plate-holder is inserted, and a spider line stretched across the aperture determines the plane of the plate in the field of the eye-piece. The focus of the different parts of the spectrum, or for the same part at different temperatures, may therefore, be found by visual observation of the lines in the solar spectrum. For monochromatic light there is of course no distinction between visual and photographic focus.

Both the camera and the visual telescope are fitted with "quartered" screws,* so that, when dropped into place, they are tightened by one-eighth of a turn.

For directing the telescope during an exposure, the method adopted at Potsdam has been followed. A small telescope, movable through a short arc, receives the light reflected from the first surface of the prism nearest to the collimator. After a few trials the straight tube at first used was cut in two, and a totally reflecting prism was inserted in a suitable mounting, the "broken" telescope thus formed allowing the observer to take a more comfortable position. A small incandescent electric lamp with a red glass bulb is inserted in the side of the collimator where it will throw light on the inside of the slit to illuminate the latter during exposure, so that it can be seen in the following telescope. I do not know whether this will prove to be a useful device or not.

* Mr. Brashear suggests this name as preferable to the more common expression "mutilated" screw, used by artillery men and mechanics.

XUM

Plate VII represents the spectroscope arranged for photography of stellar spectra.

The weight of the prism-box, complete, without camera or observing telescope, is 12 pounds. The visual telescope weighs 2 pounds, and the camera with its side braces and plate-holder, weighs 4 pounds, 1 ounce. According to the arrangement of the apparatus the total weight of the spectroscope varies from 56 to 67 pounds.

To restore the balance of the main telescope when the spectroscope is removed, 100 pounds or less must be added to the eye-end, and for this purpose iron counterpoise weights are provided, as follows: four weights of 25 pounds each, two of 10 pounds each, and four of two pounds each. With these weights, which can be slipped along the telescope tube for a short distance, the spectroscope can be balanced with any desired arrangement. The rods to which the weights are secured are at such a distance from the tube that the balance in right ascension is never appreciably disturbed even when the whole spectroscope is removed, a point of considerable practical importance.

Preliminary trials have demonstrated the great convenience of this instrument in all kinds of spectroscopic work, and I cannot speak too highly of its mechanical execution. Optically, the most noteworthy feature is the use of simple prisms in the train for spectrum photography, instead of the compound prisms which have been so generally adopted of late. This was regarded as an experiment in designing the instrument, and after a number of trials I am still doubtful as to which method is the more advantageous. If the spectrum were intended to be viewed with an eye-piece, there is little doubt that the advantage would lie with the simple prisms as indicated by theory; but in photographic work the resolution of lines is limited in a less degree by the resolving power of the prisms than by the coarseness of grain of the photographic plate. Hence an instrument with moderate resolving power and considerable dispersion might be more efficient for photographic purposes than one with high resolving power and low dispersion.

In this connection a statement of some of the data regarding the construction of the prism train will be of interest. Each prism has a refracting angle of 60°, which, it may be noted, is very nearly the polarising angle for Hγ. The glass is dense and slightly yellow, but optical examination led me to think that the absorption of the upper end of the spectrum was not sensible as low as Hγ and above this line there was no occasion to work.

The Allegheny Observatory Spectroscope.

6. Arrangement with Train of Prisms for Photographing Stellar Spectra.

XUM

The approximate minimum deviations for some of the principal Fraunhofer lines are as follows:

B	55°	54′
C	56	8
D	56	51
b_1	57	58
F	58	41
Hγ	60	18
G	60	26
H	62	4
K	62	15

One millimetre on the photographic plate in the vicinity of the Hγ line = 12.5 tenth metres, the scale of the photographs being therefore slightly greater than that of photographs taken with the Potsdam spectrograph (1mm = 13.0 tenth-metres). With the high power eye-piece previously mentioned everything in Rowland's map can be seen in this part of the solar spectrum. The definition is superb. Considerably less detail appears in a number of photographs of the same region, but the four fine lines between λ 4337.2 and λ 4338.4 are separately shown, and the double line close to Hγ, at λ 4339.8, is divided.

On these plates the maximum photographic effect was considerably below Hγ, somewhere near λ 4500, and the darkening of the film fell off rather rapidly above Hγ to the upper limit of the plate. This position of the maximum might be due to,—(1), a real maximum sensitiveness of the plates used for a part of the spectrum below Hγ; (2), the rapidly increasing dispersion toward the violet end of the spectrum; (3), increasing absorption of the glass toward the violet. A photograph taken with the light flint single prism ruled out (1), and showed that the true cause was to be found in the combined effect of (2) and (3). I am still doubtful whether the absorption of the prisms has any considerable effect in reducing the brightness of the spectrum at the Hγ line. With a slit-width of 0.001 inch, an exposure to the Moon of five minutes gave a spectrum which was quite strong to the eye, but too weak and granular to bear much magnification The most suitable exposure for a measurable negative was from fifteen to thirty minutes. It might be more advantageous to use prisms of lighter flint, with somewhat greater refracting angles, and obtain the same linear scale of the photographs by increasing the focal length of the camera.

In general, this instrument is very nearly what I think a complete spectroscope for a telescope of moderate dimensions should

XUM

be. To adapt it to larger telescopes, I do not see that any change should be made, except to increase the length of the collimator in order to keep the same effective aperture. The longer collimator would be required in this case because the ratio of focal length to aperture is usually greater for large than for small telescopes.

A duplicate of the Allegheny spectroscope has been ordered for the new U. S. Naval Observatory, and another will probably be made for the University of Chicago.

ON THE PROBABLE SPECTRUM OF SULPHUR.*

JOSEPH SWEETMAN AMES.

While pursuing in the winter of 1889 some investigations on the spectrum of hydrogen I was surprised to find on several of my photographic plates lines which evidently had no connection with hydrogen. These lines formed most beautiful series, bearing a striking resemblance to the B group of the solar spectrum. In some cases the series overlap, in others they are perfectly distinct. The head of each series is towards the shorter wave-lengths, and the lines are generally grouped in pairs. There is one very faint series of pairs beginning about wave-length 2860; at wave-length 3020 a series of single lines begins; from wave-length 3065 to wave-length 3200, there is almost hopeless confusion of overlapping series, most of the lines being strong and sharp; and at wave-length 3200 begins a series of at least 12 pairs, which in its intensity and in all its physical properties, is remarkably like the B group.

My reasons for believing these series to belong to the spectrum of sulphur are largely negative ones. The plates on which they appeared were taken consecutively on the same day. Since then I have tried to secure the same or similar conditions; but not once have I found a trace of the lines. I was using vacuum tubes containing large aluminium electrodes; and the hydrogen was admitted to the tubes over a mercury trap. Plugs of sulphur, blocked by glass wool, were interposed in the connecting tubes to stop the mercury vapor. It sometimes happened that the hydrogen would bubble up through the mercury trap faster than was desirable; and it is perfectly possible that with the mercury vapor, traces of which could always be detected in my tubes,

* Communicated by the author.

some particles of sulphur were carried through. The only impurity detected in my tubes was mercury. Traces of water vapor always linger on the walls of vacuum tubes, but its spectrum is known. I have compared these new lines with all the spectra at my disposal, and can find no agreement. The fact that these lines form series so wonderfully like the B group, which is due to oxygen, is an argument, however faint, that they may belong to sulphur, since oxygen and sulphur are so closely connected chemically.

Being unable to convince myself that the spectrum which I obtained was really due to sulphur, I have never measured my plates carefully. I publish this note now only in the hope that some investigator may be able to succeed better than I in securing the necessary conditions for repeating my observation.

JOHNS HOPKINS UNIVERSITY,
Nov. 26, 1892.

STUDIES ON THE PHOTOGRAPHIC SPECTRUM OF THE PLANETARY NEBULÆ AND OF THE NEW STAR.*

EUGEN VON GOTHARD.

In the months of September and October I had, through the kindness of my friend, Dr. N. von Konkoly, the opportunity of taking some interesting photographs with an excellent objective prism of 10 inches aperture, which had been polished in the most perfect manner by Dr. Max Pauly, in Mühlberg, D. E. (Saxony). Herr Pauly, an exceedingly skillful amateur, has a passion for glass-grinding. He has done already several very good and large objectives, even of seven-inches aperture. I attached the prism to the upper end of my 10¼-inch reflector, and photographed the spectra with my ordinary star camera.

On the present occasion I will merely speak of my nebulæ-photographs in connection with my studies on the new star.

So far I have taken with the objective-prism seven planetary nebulæ, the Ring nebula in Lyra, and the Dumb-Bell nebula. The drawings represent the photographs on a larger scale. The wave-lengths are given in tabular form at the end of the article.

The photograph I took of the Dumb-Bell nebula shows its image as if no prism had been used. By measuring the nucleus from the hydrogen lines of the neighboring stars' spectra, I suc-

* Translation by Miss Madelaine Fummel, communicated by the author.

XUM

ceeded in determining the wave-lengths of light, which the photograph had recorded. I found $\lambda = 372.4\ \mu\mu$ identical with the line which, in the large, irregular nebulæ, is always the brightest.

Gen. Cat. No. 4447. Ring nebula in Lyra. Sept. 17. Exposure 3 hours 30 minutes (Fig. 1). The spectrum consists of six rings, the first of which $\lambda = 502$ can also be seen with the spectroscope. It is considerably less elliptical than the others, which more or less encroach on each other. The last is the most intense, and a singularly true image of the nebula. I fancy I can see in the centre (though not with certainty) the little star, which I discovered in 1887 by the aid of photography.

Gen. Cat. No. 4964. Planetary nebula in Andromeda. September 25. Exposure one hour. (Fig. 2.) In a pretty large, continuous spectrum six knots of light are visible. The first, second and third are very intense. There also occurs a line which is absent in the Ring-nebula, at $\lambda = 470\ \mu\mu$, but the most intense line of the Ring-nebula is entirely absent. It is very strange that this line $\lambda = 372$, which is always very bright, almost the brightest in the larger nebulæ, should either be absent or very faint in the planetary nebulæ. The third line appears to be double.

Gen. Cat. 4373. Planetary nebula in Draco. Oct. 13. Exposure 70 minutes. (Fig. 3.) The continuous spectrum is considerably stronger and narrower, the knots are smaller and elongated, II is absent, VII present, very large and diffuse.

Gen. Cat. 4514. Planetary nebula in Cygnus. Oct. 14. Exposure one hour. (Fig. 4.) The continuous spectrum is much stronger, consequently the nebular lines are not very conspicuous; otherwise the spectrum agrees with that of 4373.

Gen. Cat. No. 4628. Planetary nebula in Aquarius. Oct. 27. Exposure one hour. (Fig. 5.) Almost identical with 4964, except that line VII is present. The continuous spectrum is not so broad, but the knots of light are larger.

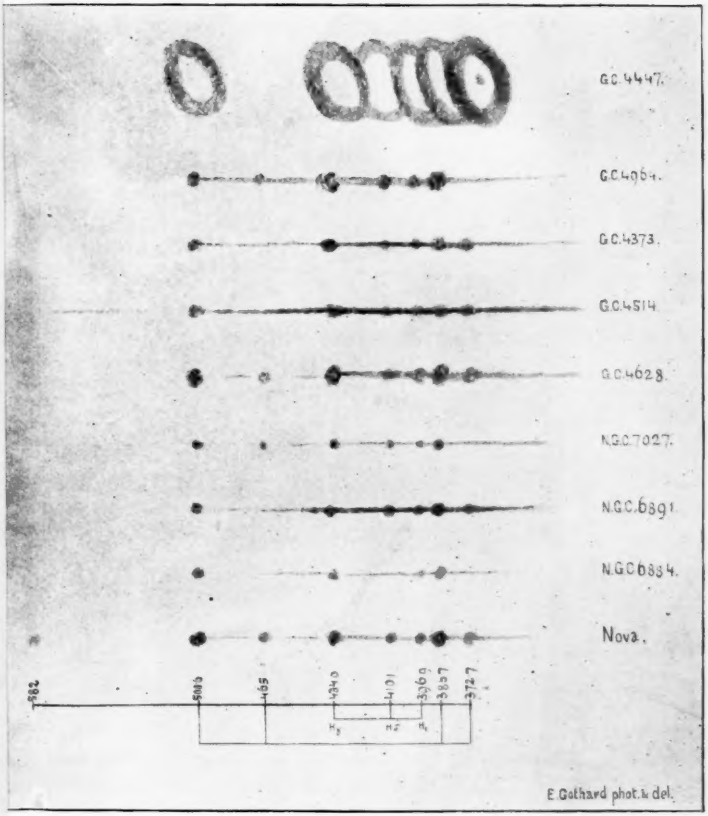
New Gen. Cat. No. 7027. Webb's planetary nebula. Oct. 22. Exposure one hour. Magnitude 8.5. (Fig. 6.) The continuous spectrum is very fine, the knots small, III is especially intense, small, sharp.

New Gen. Cat. No. 6891. Copeland's planetary nebula. Magnitude 9.5. Oct. 27. Exposure one hour, thirty minutes. (Fig. 7.) The spectrum very much resembles that of G. C. 4514, the continuous spectrum being very strong.

New Gen. Cat. No. 6884. Copeland's planetary nebula. Oct. 28. Exposure two hours. (Fig. 8.) Spectrum very faint. Be-

XUM

PLATE VIII.


G.C.4447.
G.C.4064.
G.C.4373.
G.C.4514.
G.C.4628.
N.G.C.7027.
N.G.C.6891.
N.G.C.6834.
Nova.
5002
4955
4340
4101
3969
3837
3727
E. Gothard phot. & del.

sides the three brightest knots I, III, and VI, only V can be seen.

These photographs were taken with the objective-prism on Schleussner's orthochromatic plates. In order to determine the wave-lengths it proved necessary to take some of the brightest with the spectrograph, which, by using a slit, permits of photographing a comparison-spectrum. For this purpose I took with my quartz-Iceland-spar spectrograph the following nebulæ: Oct. 1, G. C. 4964, exposure 2 hours, 30 minutes; Oct. 29 and 30, No. 4628, exposure 5 hours; and on Oct. 10, the Orion nebula with an exposure of 2 hours, 30 minutes. The nebula and hydrogen spectra having been taken on one plate it was possible to identify the lines and to get a starting-point for determining the wave-lengths.

With a greater dispersion line III in No. 4964 appeared double, another faint line being found at $\lambda = 436$. I also measured a line before line VI at $\lambda = 388.9$ and another at $\lambda = 379.6$; both are hydrogen lines. No. 4628 much resembles it but is fainter, the nebula having been lower and the atmosphere very unfavorable. Thus three lines, which were measured in the other spectra, are absent. In reference to the Orion nebula I beg to state that an ordinary plate had been used instead of an orthochromatic one, for which reason the spectrum apparently begins at Hβ. Besides the nebular lines I obtained near nebular line VII a number of hydrogen lines.

The measurements are summarized in the table.

At the time I began my studies with the objective-prism, the new star in Auriga had again taken in the morning sky a favorable position for observation. Before describing my photographic results I beg to briefly communicate my observations made in the spring.

When the star was at its maximum brightness the spectrum consisted of a bright, continuous spectrum, reaching far into the ultra-violet. On its photograph from 40 to 43 bright and from 12 to 13 dark lines can be distinguished. The hydrogen lines as well as some others occur both bright and dark, the former very much displaced toward the red, the latter toward the violet end of the spectrum.

This beautiful spectrum, which I photographed six times and observed repeatedly with the eye, disappeared gradually with the brightness of the star. In the middle of March it was so faint that all further pursuit had to be abandoned.

In the autumn, on Sept. 15, I observed the spectrum for the first time with the objective-prism. It appeared among the num-

erous spectra of the neighboring stars like a somewhat greenish star of the 10th magnitude. By photography I obtained much handsomer, unexpected results.

As the spectrum taken on Sept. 15 could not be seen on the plate, I photographed it again on Sept. 19 with an exposure of 45 minutes. This time six spots of light were visible, which on renewed inspection could now also be detected on the first plate. A comparison with other photographs, especially with those of the planetary nebulæ, gave the surprising result that the spectrum of the new star perfectly agrees with that of the planetary nebulæ.

At first I thought it a mistake and took the region without the objective-prism. Comparing the photographs with former ones taken in the spring, the coincidence of the two photographs appeared so perfect as to exclude all doubts.

Further photographs taken on Sept. 27, with 2 hours, 15 minutes exposure, and Oct. 28, with 3 hours exposure, produced even more perfect pictures, which, compared with the above described spectra, give the highly interesting result, that the new star has changed into a planetary nebula.

The most beautiful spectrum, taken on Nov. 28, shows eight spots of light. The first is very faint and coincides with the brightest yellow line $\lambda = 582$ (after Vogel) of the Wolf-Rayet stars 4013 and 3956. The second is the chief nebular line $\lambda = 500.62$ (after Keeler). The next is again present in the Wolf-Rayet stars $\lambda = 465$ (according to my own measurements taken on the photographed spectra). The three following are hydrogen lines $H\gamma$, $H\delta$ and $H\varepsilon$. There are further present two more nebular lines $\lambda = 386.7$ and 372.7 (after my own measurements).

The difference in the wave-lengths appears insignificant upon the consideration that the measurements of the diffuse, somewhat elongated spots are very uncertain, and the entire length of the spectrum is but 3mm. Line $H\delta$ shows the greatest difference; possibly another line is present there.

The results of the studies may be summarized as follows:

(1.) The spectra of the planetary nebulæ agree typically although they slightly differ in the intensities.

(2.) Hydrogen is represented in each spectrum by three or more lines.

(3.) Besides the hydrogen lines the presence of two characteristic nebular lines, $\lambda = 500.6$ and 386.7, can with certainty be proved in all, a third $\lambda = 372.7$ in most spectra. The fourth line $\lambda = 464\text{-}470$ seems to be less frequent.

(4.) Line $\lambda = 372.7$ which is always very intense in the large irregular nebulæ, is always very faint in the true planetary nebulæ, which fact marks a considerable difference between the two kinds.

(5.) In each spectrum can be detected a more or less developed continuous spectrum, corresponding to a nucleus or a condensation.

(6.) The physical and chemical state of the new star resembles at present that of the planetary nebulæ.

(A.) *Table of Wave-Lengths of the Spectra photographed with the Objective Prism.*

			I.*	II.*	III.†	IV.†	V.†	VI.*	VII.*
1	G. C. No.	4447 —	502	—	434	411	396.5	386.5	373 $\mu\mu$
2	"	4964 —	501	470	434	409	397	386.5	—
3	"	4373 —	502	—	434	410	396.5	386.5	373
4	"	4514 —	502	—	434	410	396.5	385.7	371
5	"	4628 —	501	468	434	408.5	396	386.5	372
6	N. G. C.	7027 —	500.7	464	434	410	395	385.7	—
7	"	6891 —	502	—	434	410	396	386.5	372
8	"	6884 —	500.5	—	434	—	395	386.5	—
9	New Star	¦582	500	464.2	434	407.7	395	385.5	372

* Nebular lines. † Hydrogen lines.

(B). *Table of Wave-Lengths of Spectra taken with the Quartz-Iceland-Spar Spectrograph.*

	I.	1.	II.	2.	III.	IV.	V.	3.	VI.	4.	5.	6	VII.
Orion nebula...	*	486.1	...	...	434.0	410.1	396.9	388.9	386.7	383.3	379.6	376.7	372.7
G. C. 4964.....	500.8	...	469.0	436.0	434.0	410.1	396.9	388.9	386.8	...	379.6	...	...
G. C. 4628.....	500.9	...	...	...	434.0	410.1	396.6	388.8	386.7	...	...	...	...
Hydrogen lines	...	486.1	...	...	434.01	410.10	396.89	388.78	...	383.45	379.69	376.94	...

* Of the Orion nebula I, the chief line, is missing, an ordinary plate having been used, and not, as for all the others, an orthochromatic one.

My manuscript was already completed when I received the October number of ASTRONOMY AND ASTRO-PHYSICS. I have been much pleased in finding that the observations of Mr. W. W. Campbell of the Lick Observatory, substantially confirm my own, and that he also came to the conclusion that the spectrum of the new star is identical with that of the planetary nebulae.

I beg to briefly compare and discuss our respective observations made with very different instruments.

Mr. Campbell with the far greater aperture of his powerful 36-inch objective, was able to see the lines far better and more distinct; he even observed several times the duplicity of those lines which appeared to me to blend on account of the small size of the spectrum (the entire length of 580–373 being but 3 mm).

Naturally Mr. Campbell was able to determine the wave-lengths with greater accuracy.

XUM

	1	2	3	4	5	6	7	8	
Campbell	575	500.2	495.3	468.5	463.4	446.6	436.0	433.6	(Sept. 7.)
Gothard	580	500	—	464.2		—	—	434	(Oct. 28.)

1, 2 (4, 5) and 8 are identical with the lines I observed, 7 is present in the nebula G. C. 4964 ($\lambda = 436.0$); as for the others, I could find no trace of them on the plate.

Most probably I did not determine line I with sufficient accuracy, my scale being not reliable enough for this part, I inferred the wave-lengths from Vogel's observations of the Wolf-Rayet stars. Very striking and instructive are the considerable differences in the intensities of the single lines.

	1	2	3	4	5	6	7	8
Campbell	1	10	3	0.4		0.1	0.8	0.1
Gothard	1	8	—	4		—	—	10

No. 8, decidedly the hydrogen line Hγ, is, according to Mr. Campbell's measures, 100 times fainter than No. 2. From my own observations it is the most intense line of the entire spectrum. The solution of these differences is to be found, I think, in the different instruments employed.

Mr. Campbell works with a large glass objective of considerable thickness which entirely absorbs the refrangible rays of the spectrum. I am working with a silver-on-glass reflector with a crown-glass prism which at its thickest place is hardly 30 mm. Consequently, I am able to utilize those rays which can be photographed.

Mr. Campbell's observations have not only reassured me respecting the reliability of my results but they have also given me the satisfaction that my moderate sized instrument, with a rational utilization of photography, is capable of producing exceptional results not only in photographing very faint objects, as Professor Dr. H. C. Vogel, Director of the Potsdam Observatory, described in the *Astr. Nachr.*, No. 2854, but also regarding the spectroscopical study of extremely delicate objects such as the Nova, can compete with great refrctors.

It has always been a puzzle to me why this inestimable property of the reflector should not be more valued or used to better advantage.

Astro-Physical Observatory Hereny, Hungary.

Nov. 18, 1892.

THE SPECTRA OF HOLMES' AND BROOKS' COMETS (*f* AND *d*, 1892).*

W. W. CAMPBELL.

The spectrum of the very interesting comet discovered by Holmes is of an extreme type and probably unique. Visual observations made November 8 and 9 showed a continuous spectrum for all parts of the comet. It extended from near D to above G for the nucleus, for the very condensed and nearly circular coma (about 5′.5 in diameter), and for the very condensed tail seen within this coma. Outside the coma, in the direction of the tail, a very faint glow was just visible in the high-power finder of the spectroscope (which would probably be seen to better advantage under a low power).

This also gave a continuous spectrum, though very short, in the yellow and green. The position of maximum brightness in the spectrum was near λ 515, which doubtless was due to the presence of a slight trace of the usual green band. But except for the fact that the maximum brightness was higher than is generally the case in continuous spectra it would have escaped detection. The increased brightness was more noticeable in the spectrum of the very faint parts of the comet than in that of the bright parts. There was possibly a trace of the yellow band; but if so, it was exceedingly faint. Photographs of the spectrum extending from F to Hδ show it as continuous, but the wide slit required leaves it in doubt whether the Fraunhofer lines were present or not.

The spectrum of Brooks' Comet was (Nov. 9) of the usual type. The spectrum of the nucleus was continuous. The yellow and blue bands were poorly defined, but their lower edges were approximately at λ 561 and λ 472. The lower edge of the green band was sharp enough to measure with considerable accuracy, and was at λ 5152 ± 0.7.

MT. HAMILTON, Nov. 10, 1892.

ON THE DISTRIBUTION OF STELLAR TYPES IN SPACE.*

J. MACLAIR BORASTON.

Desiring to obtain a general view of the stars contained in the Draper Catalogue of Stellar Spectra in which the differences of spectrum and relative distribution as to type should readily

* Communicated by the author.

appear, I constructed two series of charts upon an isographic projection, the first series containing all the stars of the D. C., numbering 10,351, and the second series only those stars the "observed brightness" of whose spectra did not fall below 6.25 on Professor Pickering's scale, which ranges from 4.0 (bright) to 8.0 (faint), the estimation being made for intensity of photographic action at or near the hydrogen line G. The number of stars contained in the expurgated series is 4334. I prepared this latter series that I might be able to work with confidence on the smaller number of stars, since, upon Professor Pickering's own admission, any spectrum fainter than 6.25 on the scale mentioned might fail to exhibit characteristics differentiating it from classes A, E and H, under which heads nearly all faint stars have been ranked.

To render the differences of spectrum apparent in the charts, I employed various colored inks, which, graduating down the spectrum from deep violet to red, might represent the gradation in the classes of spectra, from A, the first class of Type I to M, which includes the stars of Type III. I arranged that violet should be the fundamental color of the shades representing classes A, B, C and D constituting Type I, which are characterized in the case of Class A by a nearly continuous spectrum in which appears the series of absorption lines of hydrogen and the K line, the latter with varying intensity; and in the case of Class B, by the presence of the above and additional lines, the latter being most frequently 402.6 and 447.1. Classes C and D are numerically insignificant. The classes E to L mark varieties of Type II, the general features of which are that the brightest portions of the spectrum lie between K and F, the K line being nearly as strong as the H line, and the other lines faint.

When F, H and K only are visible, and no sudden change in intensity takes place, the star is placed under Class E. This class was represented by dark blue, and Class F, in which additional hydrogen lines are present, by light blue. Green was used for Class G, which is characterized by the presence of other lines in addition to those of Class F. A general property of Classes H, I and K is the greater intensity of rays exceeding λ 431 as compared with those of less wave-length. Under H is ranged the first-class so distinguished, I denotes additional lines, and K the presence of bright bands. L is numerically unimportant. Various tones of yellow and orange were employed to render these distinctions visible. M includes all stars of Type III in the spectrum of which a sudden change of intensity takes place at λ 476.2, rays of greater

wave-length than this being fainter than those which are shorter. This class was represented by red, which closed the series.

It became evident in charting that stars having the most highly differentiated spectra were generally of the higher magnitudes, making it more than probable that the greater amount of light at command rendered visible those characteristics which entitled them to separate classification. It may therefore be concluded that the Classes A, E and H, under which headings are ranged the simplest and least developed spectra in their respective types and sub-types, include spectra of a higher degree of differentiation which, owing to deficient light, cannot be rendered evident. For this reason, when laying down curves to represent the relative numerical distribution of the various kinds of spectra, I gave one curve for Type I (Class A, B, C and D), a second for Classes E, F and G, a third for H, I, K and L, and a fourth for the latter two groups combined, which curve, therefore, represents Type II.

The curves were laid down for divisions of equal area, and in doing so, I followed Professor Pickering's divisions, in which zones are marked off by parallels at $+ 61° \ 2'.7$, $+ 30°$, $0°$, and $- 30°$, the circumpolar zone being divided into three parts by meridians at 0^h, $VIII^h$ and XVI^h; the zone from $+ 61° \ 2'.7$ to $+ 30°$ into nine divisions of $2^h \ 40^m$ each starting from 0^h; and the two equatorial zones into twelve sections respectively, also starting from 0^h, each section covering 2^h in R. A. There thus result 36 divisions of equal area, covering three-fourths of the sphere.

The curves were first laid down for all stars included in the D. C., then successively for those the inferior limit of whose observed brightness did not sink below 6.25, 5.75, and 5.25 respectively. At 5.25 the numbers of the spectra were too reduced to make it profitable to further extend the examination by this method.

It was found that the curve for Type I in the circumpolar zone was uniform for each of the four limits of observed brightness. In the division 0^h—$VIII^h$, it starts from a maximum of 20-30 per cent above average* in Cassiopeia and Camelus; in the second division $VIII^h$—XVI^h (Ursa Maj., and Min., and Draco) it falls to the minimum of about 30-35 per cent below average, and in the third division (Draco, Cepheus and Cassiopeia) XVI^h—$XXIV^h$, it re-ascends to an inferior maximum of about 15 per cent above average for spectra fainter than 6.25, those brighter

* Average here and throughout the comparisons means the average per division for the group of spectra and the zone under discussion.

than this giving a curve coincident with average. The curve for 'all stars' Type II, in this zone is in marked contrast to that for Type I. Starting at 15 per cent below average in division 0^h—$VIII^h$, it reaches the absolute maximum for this zone in division $VIII^h$—XVI^h and declines to co-incidence with average at XVI^h—$XXIV^h$. The curve is thus strongly anticlinal to that for Type I in this zone.

The supremacy of the second type curve for 'all spectra' in the second division of this zone is due on the one hand to an assemblage of faint E, F and H stars in Draco and Ursa Minor, and on the other to a decline in the density of distribution of first type stars after V^h 30^m R. A., which do not resume anything like the compactness observable before this point until we reach $XVII^h$ 30^m R. A. on the opposite side of the sphere.

In the sets of curves for limits of observed brightness 6.25, 5.75 and 5.25, the elimination of these faint second type stars brings the curves below those of the first type stars, and they now pass up from somewhat below average in 0^h—$VIII^h$, without pronounced deviation in $VIII^h$—XVI^h, to the maximum for these curves of from 40-50 per cent above average in XVI^h—$XXIV^h$.

This maximum for the brighter spectra of second type stars in XVI^h — $XXIV^h$ is due to a rapid increase in number and magnitude of F, I and K stars in Draco and Cepheus.

The separate curves for E, F, G and H, I, K stars, which go to form the second type curve just treated of, exhibit both here and in all other zones, the most intimate sympathy, and their averages are practically equal.

The next set of curves represents the intermediate northern zone enclosed by the parallels $+ 61° 2'.7$ and $+ 30°$, which, as stated above, is divided into nine parts of 2^h 40^m each part.

In this set the first type curve for 'all stars' starts at once in 0^h — II^h 40^m (Cassiopeia, Andromeda and Perseus) with the absolute maximum for this zone of 85 per cent above average, sustained with an insignificant decline through II^h 40^m — V^h 20^m (Perseus and Auriga), after which it descends steeply for the extra galactic region to about 10 per cent below average in V^h 20^m — $VIII^h$ (Auriga, Lynx and Gemini), and continues an even downward course through Lynx, Ursa and Leo Minor, until it reaches its minimum 60 per cent below average between X^h 40^m — $XIII^h$ 20^h (Ursa, Canes Venatici), whence it mounts through N. Boötes, Corona, S. Draco and N. Hercules less abruptly than in the descending portion of the curve, to an inferior maximum 20 per

cent above average at XVIII^h 40^m — XXI^h 20^m (Lyra and Cygnus) suffering a slight decline again between XXI^h 20^m—XXIV^h (Cygnus, Lacerta, Andromeda).

The second type curve for 'all stars' for this zone, whilst sympathizing with that of Type I in descending evenly from a maximum of 35 per cent above average in division 0^h–II^h 40^m to coincidence with average at V^h 20^m–VIII^h, parts company with the first type curve in the last mentioned division, for whilst the latter curve steadily declines to its minimum at X^h 40^m–XIII^h 20^m the second type curve as steadily rises to a secondary maximum at VIII^h–X^h 40^m, all but equal to that at 0^h–II^h 40^m, though it afterwards decends to its minimum about 30 per cent below average at X^h 40^m–XVI^h, in fair coincidence with the first type minimum.

This independent second type maximum is due to a pronounced condensation of faint E, F and H stars on both sides of meridian IX^h in Lynx and Ursa.

After the fairly coincident minima of both curves at X^h 40^m—XVI^h, the second type curve attains still a third maximum almost equal to the former one in the division XVI^h—XVIII^h 40^m, thus anticipating the maximum in the first type curve, which only occurs at XVIII^h 50^m—XXI^h 20^m in divergence from that of the second type, which drops from its third maximum to 25 per cent below average in this division.

This third second type maximum is again the result of intense local condensation of faint E, F and H stars about meridian XVIII^h on the line of division between Lyra and Hercules.

On coming to an examination of the curves in this zone for limits of 'observed brightness' 6.25, 5.75 and 5.25, the inequalities apparent for 'all stars' vanish, and the curve for Types I and II undulate in extraordinary uniformity throughout the zone, the maxima for both curves occurring in those divisions which are traversed by the galaxy.

An unique phenomenon in this zone lies in the fact that the maxima for first type spectra brighter than 6.25 in the galactic division XVIII^h 40^m—XXI^h 20^m, exceeds by about 15 per cent that occurring in the galactic division II^h 40^m—V^h 20^m, an inversion of the rule followed in all other zones for every limit of 'observed brightness,' in virtue of which the absolute maximum of the first type curve is always located in the preceding half of the galaxy. The present exception is traceable to the rich first type region in Lyra and Cygnus.

Underlying the second type curve in this zone, the separate

curves for E, F, G and H, I, K exhibit the closest alliance, both by common conformity to the first type curve, where conformity exists, and by a common deviation from it, where deviation takes place. Their averages are again practically equal.

In the north equatorial zone + 30° — 0°, divided, as stated, into twelve parts of 2^h each, the first type curve starts in 0^h—II^h (Pisces) from about 15 per cent below average, mounts sharply to the absolute maximum for the zone of more than 100 per cent above average at IV^h—VI^h (the result of the rich first type region in Taurus and Orion), and then, sustained at about 65 per cent above average between VI^h and $VIII^h$ by the first type stars of the galaxy, drops precipitately to 25 per cent below average at $VIII^h$—X^h (Cancer, E. Leo, N. Hydra), whence it continues without important break through Leo, Coma, N Virgo, to the minimum of 50 per cent below average at XIV^h—XVI^h (S. Boötes, Serpens), rising again to an inferior maximum of about 50 per cent above average in the galactic division $XVIII^h$—XX^h, (N. Aquila, Sagitta, W. Vulpes), whence it falls again to 50 per cent below average at XX^h—$XXII^h$ (Delphinus-E. Vulpes, Equus and W. Pegasus) with a slight final rise in Pegasus) $XXII^h$—$XXIV^h$.

The second type curve for 'all stars' in this zone in contradistinction to the first type curve, starts in the relatively rich second type region Pisces 0^h–II^h, about 60 per cent above average, and gradually sinking to coincidence with average at that point where the first type curve attains its greatest eminence in Taurus and Orion, afterwards rises as the former falls, until it crosses the first type curve in Cancer and the adjacent parts of Leo and Hydra, maintaining its supremacy through Leo, Virgo and Coma, when it drops in XVI^h-$XVIII^h$ to its minimum of 30 per cent below average in absolute coincidence with the first type minimum in Boötes and Serpens. Here it recrosses the first type curve, and passes up beneath it in perfect sympathy to a coincident maximum at the point of intersection of the galaxy and equator in Aquila, whence both curves descend together to coincident minima in Delphinus and Equus, and the adjacent portions of Aquila, Vulpes and Pegasus.

For the limits of brightness 6.25 and 5.75, the second type curve does nowhere gain supremacy over the first type curve, but undulates in sympathy and subordination to it throughout the zone, with one point of difference which lies in the fact that, instead of the maxima in the preceding portion of the galaxy coinciding with the first type maxima in Taurus and Orion, they do

not occur until the following division covering N. Monoceros, Canis Minor and Gemini.

For the limit of brightness 5.25 the first type curve in this zone still coincides as to its general character with those for the lower limits, but the various maxima and minima are more abrupt. The second type curve for this limit of brightness, on the contrary, becomes almost featureless in its evenness.

Again the E, F, and G, and H, I, K curves manifest the most marked sympathy, and their averages are practically equal.

The last set of curves are those for the southern equatorial zone 0° to 30°, divided as in the case of the northern equatorial zone, into twelve sections of 2^h each.

In Cetus and Eridanus, relatively poor in first type stars, the curve starts at about 10 per cent below average, whilst the greater proportion of second type stars in this region places that curve at the maximum of 60 per cent above average, at this point. When, however, the first type curve ascends in Orion and Canis Major to the absolute maximum for this zone of about 140 per cent above average, the second type curve passes through this region at the level of average, but after the great dip in the first type curve from 140 per cent above, to 25 per cent below average in W. Hydra and N. Argo, the second type curve cuts through it at this point, gaining decided supremacy in the rich second type region in and around Crater, from which it gradually declines through Virgo and Libra, to contact with the first type curve in Ophiuchus; after which, in the entire absence of the usually strong inferior maximum occurring in first type curves in the galactic division $XVIII^h$-XX^h, the second type curve mounts alone to a pronounced maximum of 50 per cent above average, over-lapping the flat first type curve by almost double its own value, from which it descends even more precipitately in the bare region of Capricornus to about 70 per cent below average, rising slightly to contact with the first type curve in the better furnished district in Aquarius.

The curves for limits of brightness 6.25, 5.75 and 5.25 in this zone are sympathetic with and subordinate to the first type curve. A maximum coincident with that in the latter curve is observable in all at VI^h-$VIII^h$ (Canis and Monoceros). The independent second type maximum at $XVIII^h$-XX^h (N. Sagittarius and S. Aquila) is also present in all curves, though in that for the brightest order 5.25, the superior brightness of some twenty first type stars in Ophiuchus and Scorpio creates a maximum in the first type curve at XVI^h-$XVIII^h$, more pronounced than the

second type one occurring at $XVIII^h$–XX^h (N. Sagittarius and S. Aquila), in which only fifteen stars coming within the limit of spectrum brightness 5.25 are involved.

The absence of the first type maximum in the galactic division $XVIII^h$–XX^h is evidently connected with the attenuated proportions of the galaxy in Sagittarius, which is at that point a mere isthmic strip; whilst the regularity in the recurrence of the second type maximum despite the absence of the first type one, though seeming to suggest the independence of the Sagittarius group of second type stars of that all dominant first type structure, the galaxy, really accentuates, by the fact of its occurrence just here, the intimacy of first and second type stars as to their distribution.

Despite the irregularities in this set of curves, there is unimpeachable evidence of close sympathy between the two great types, and it is most patent for the limit of spectrum brightness 6.25, where the greatest number of stars is at command with reliable spectra.

The E, F, G and H, I, K curves for this zone are like a double-stranded curve in their intimate association.

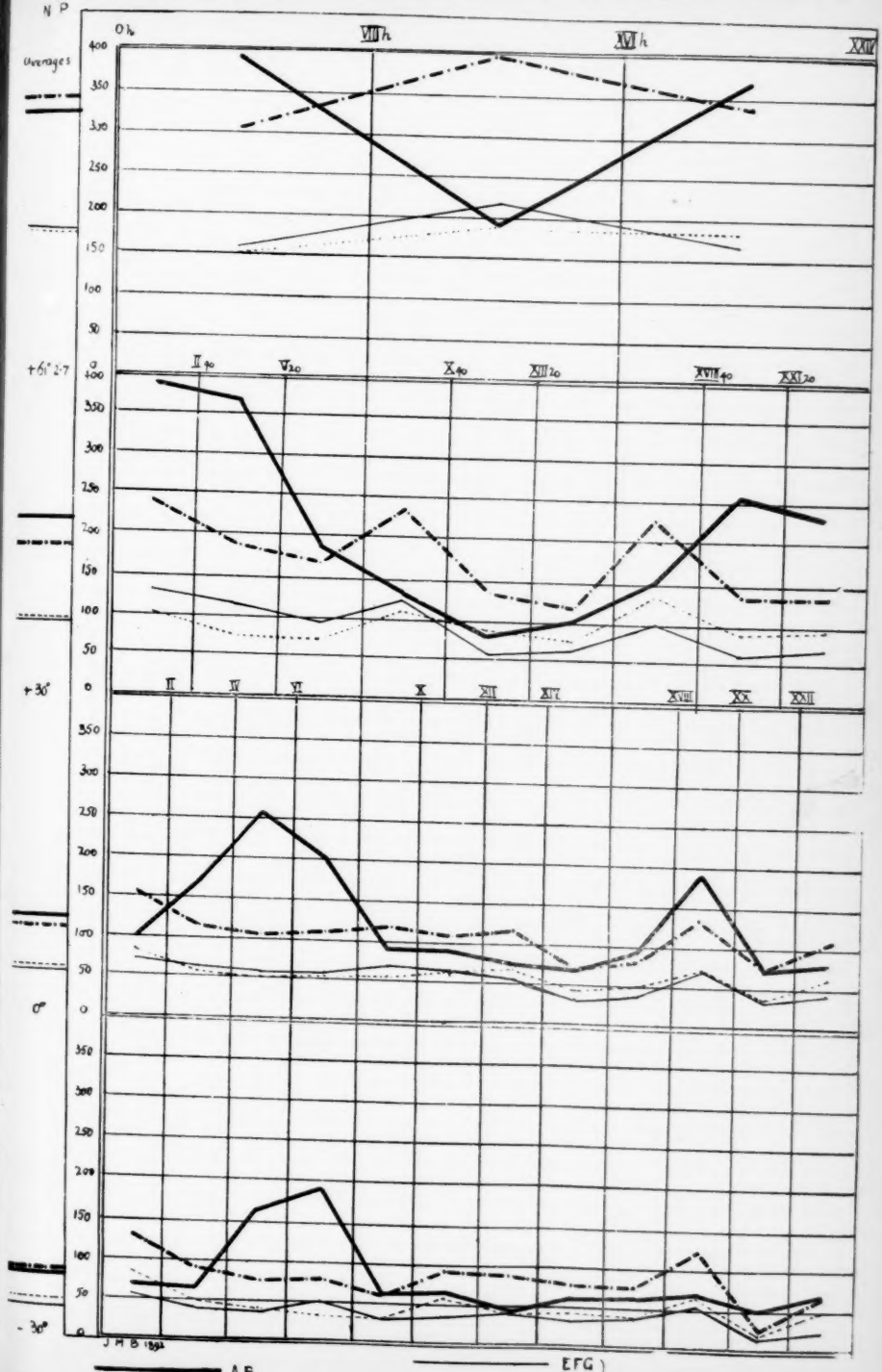
After inspection of these curves there can remain no doubt as to the solidarity of the two great types, for, whatever be the proportions of the numbers of stars entering into comparison, a manifest sympathy and parallelism of the curves representing the various groups place their common subjection to an uniform principle of distribution beyond question.

Despite the limited number of spectra of the third type in the D. C., there is an unmistakable attempt on the part of the M curve to conform to the undulations of those representing Types I and II, whilst the similar behavior of Type IV would seem to be sufficiently foreshadowed by the curve representing Chambers' catalogue of some 300 red stars. The latter type, by reason of the photographic lethargy of the light furnished by its constituents, is unrepresented in the D. C.

The unique nature of the phenomenon presented by the independent second-type maximum in the galactic region Sagittarius seemed to call for more detailed examination, and as the results are pertinent to the matter in hand they will be given here.

The following stars were identified among the brighter ones entering into the group, and their proper motions extracted from the Greenwich Catalogues. The magnitudes are photographic and from the Harvard Photometry.

Draper Catalogue 1890 Curves of Distribution for all stars (10345) Scale = 1·00

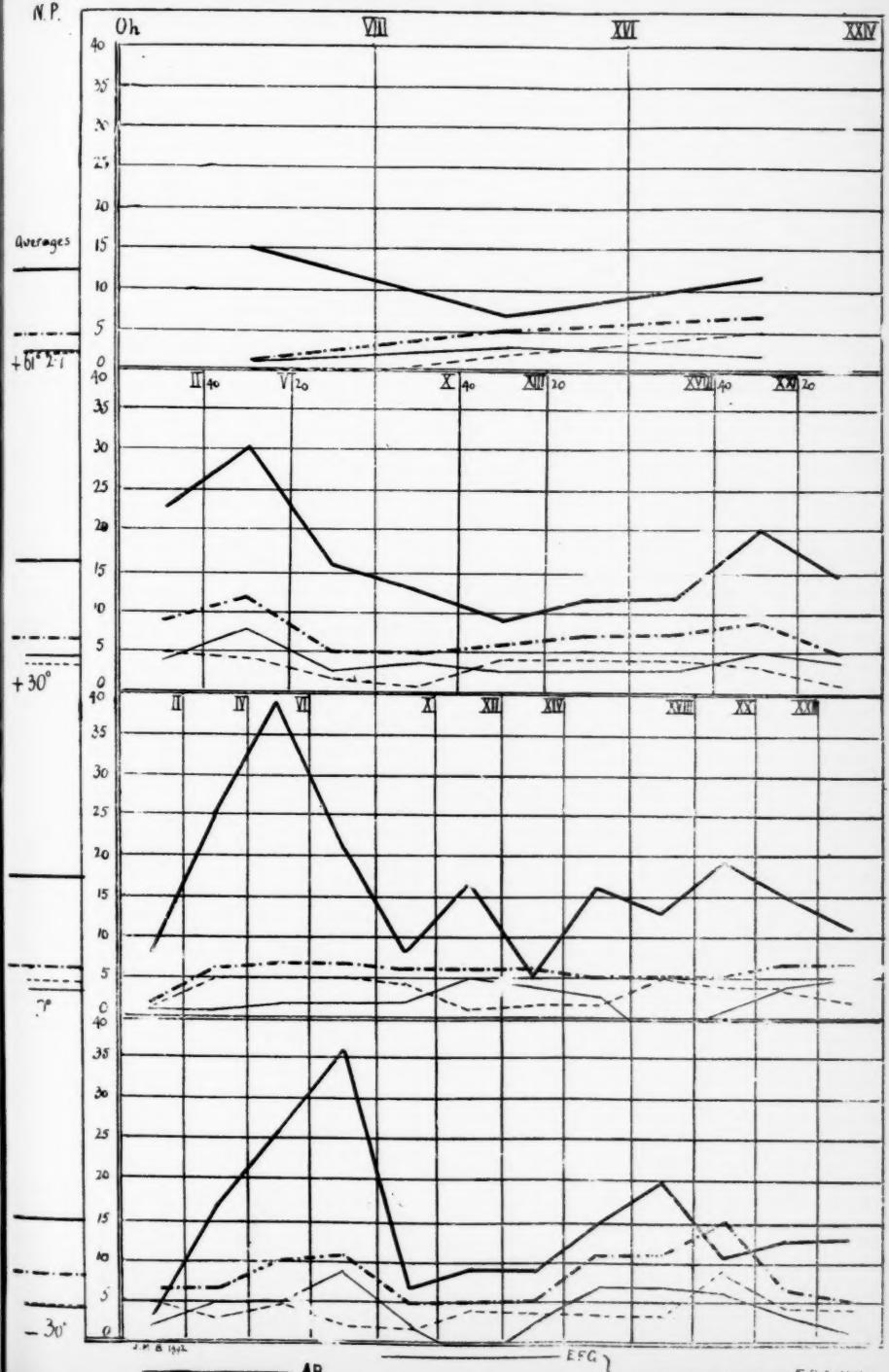


XUM

Draper Catalogue 1890

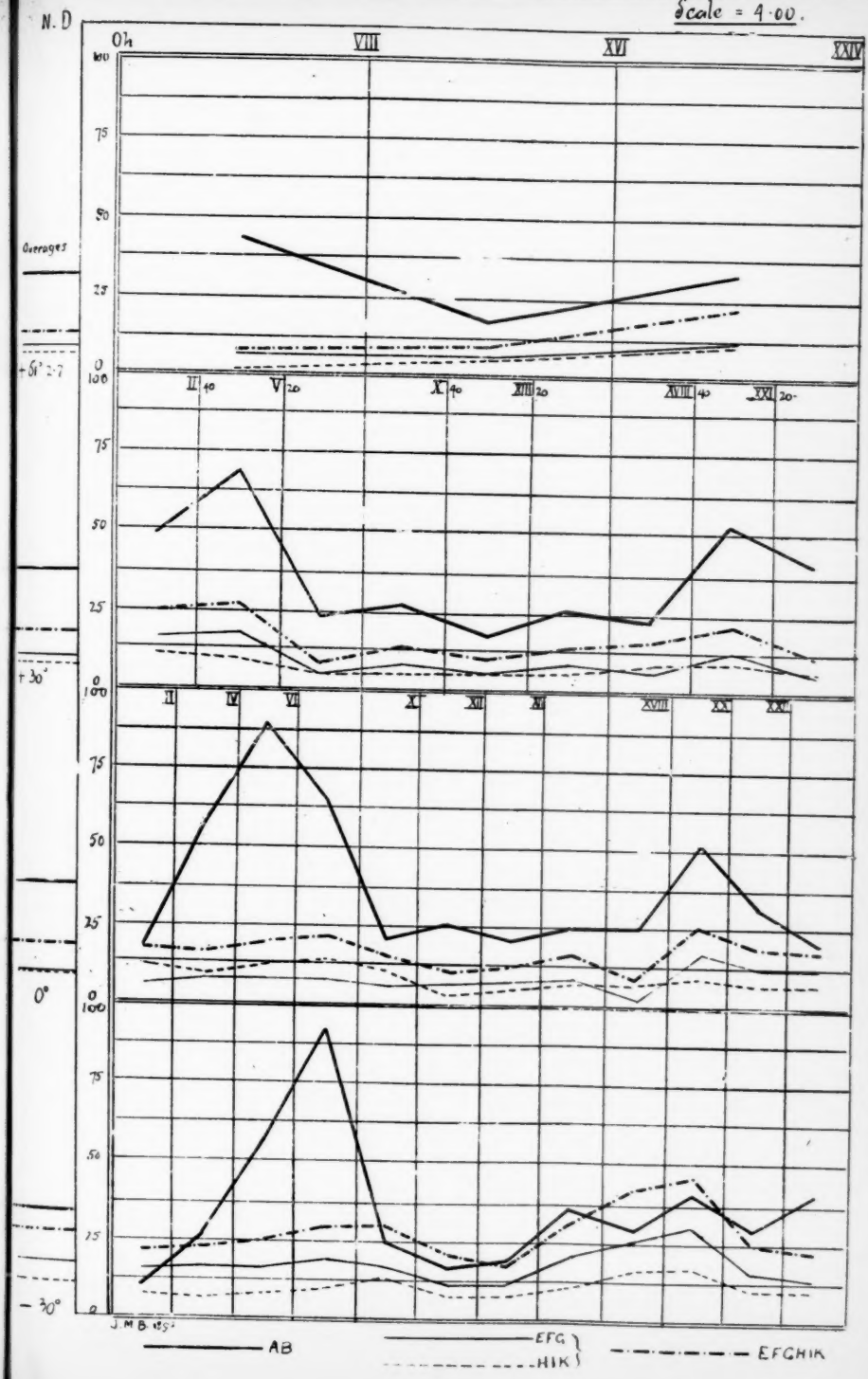
Curves of Distribution for 'Observed Brightness 5.25

Scale = 10



Draper Catalogue 1890 Curves of Distribution for Observed Brightness 5·75

Scale = 4·00.

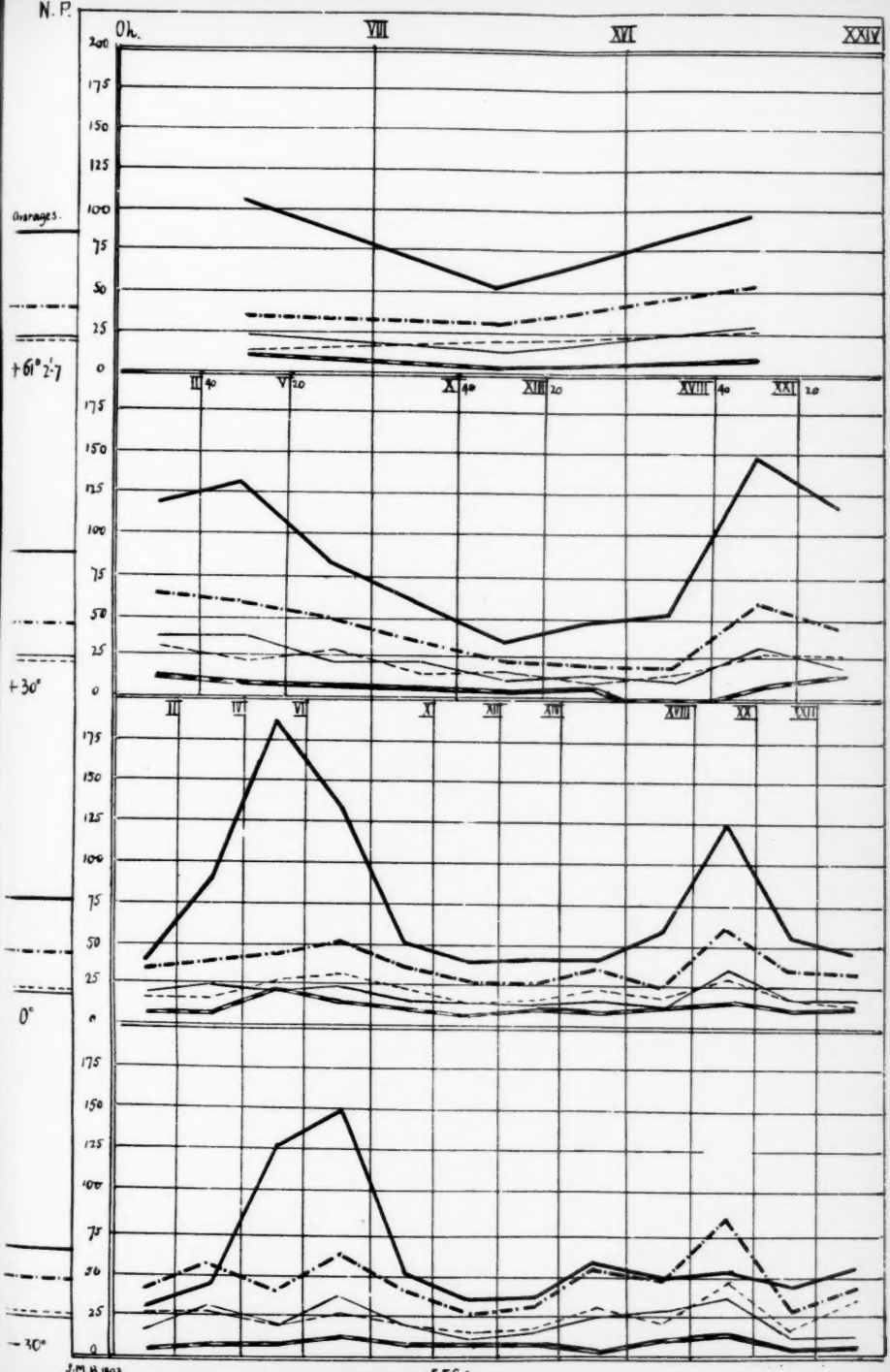


Draper Catalogue 1890

Chamber's Cat. Red Stars (293)

Curves of Distribution for 'Observed Brightness' 6·25

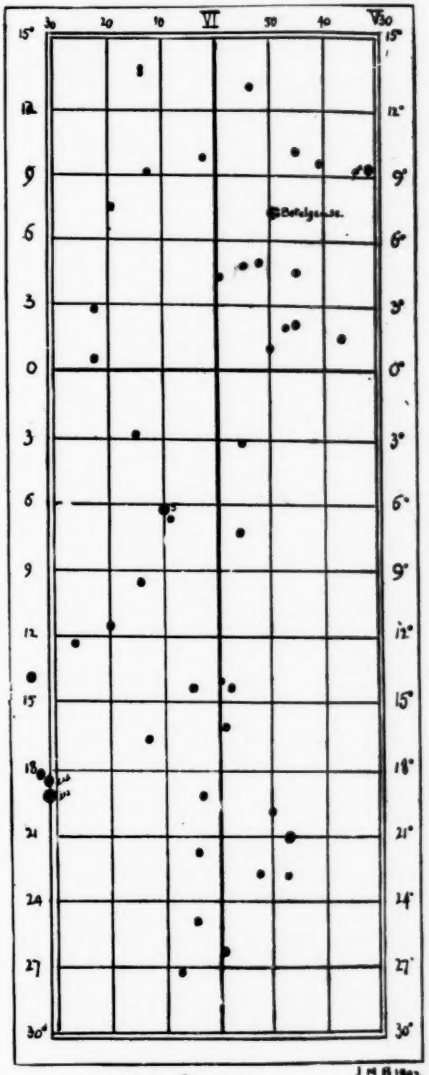
Scale = 2·00



M stars. As stars of this type are so few, the number in each division has been given at the right-hand side of the diagram.

PLATE XIII.

Preceding plates numbered IX, X, XI, XII.



XUM

Star.	Spectrum.	Mag. H. P.	Parallel. ″	N.P.D. ″	Proper Motion. ″	Angle of Direction. ° ′
4 Sagittarii	A	4.48	− .075	+ .04	0.085	241 56
Piazza XVII 323	H	6.53	− .045	+ .15	0.150	196 42
7 Sagittarii	F ?	5.32	− .090	+ .03	0.095	251 34
μ^1 "	F	4.23	− 0.60	+ .01	0.061	260 32
16 "	A ?	5.89	+ .090	+ .03	0.095	108 26
Bradley 2292	A ?	6.55	+ .045	.....	0.045	90 0
η Serpentis	K	4.62	− .585	+ .68	0.900	220 42
21 Sagittarii	H	5.94	− .045	+ .02	0.049	246 2
λ "	K	4.49	− .075	+ .24	0.251	181 48
Bradley 2318	A	4.87	.....	+ .02	0.020	180 0
" 2314	A	6.11	.....	− .04	0.040	0 0
" 2319	E	6.12	− .285	+ .08	0.296	254 19
24 Sagittarii	H	6.37	− .090	+ .02	0.092	257 28
1 Aquilæ	K ?	5.04	− .060	+ .33	0.335	190 19
2 Aquilæ	F ?	4.92	− .015	+ .01	0.018	236 19
φ Sagittarii	A	3.55	+ .060	− .01	0.061	80 33
28 "	H	5.95	+ .090	− .01	0.091	83 40
5 Aquilæ	A	5.41	+ .045	+ .05	0.067	138 0
Lalande 34875	K ?	5.93	.....	.....	.....	....
29 Sagittarii	H	6.09	− .030	− .03	0.042	315 0
30 "	F	5.81	+ .015	+ .03	0.033	153 27
33 "	H	6.17	+ .090	− .04	0.098	65 46
ν^1 "	H	5.65	− .060	+ .01	0.061	260 33
ν^2 "	H	5.65	+ .090	− .01	0.091	83 40
σ "	B	2.77	.....	+ .08	0.080	180 0
Piazzi XVIII 225	F	5.34	+ .105	− .03	0.109	74 4
ξ^1 Sagitarrii	A ?	5.26	+ .015	.....	0.015	90 0
ξ^2 "	K	4.91	− .015	+ .03	0.033	206 34
12 Aquilæ	K	5.18	+ .015	+ .04	0.043	159 26
14 "	A	5.37	+ .075	− .06	0.096	51 21
o Sagittarii	I	4.99	+ .015	+ .05	0.052	163 16
τ "	H	4.53	− .120	+ .26	0.310	204 43
π "	F	3.75	− .060	+ .03	0.067	243 27
ψ "	F	5.04	.....	+ .01	0.010	180 0
ρ^1 "	A	4.79	− .045	− .03	0.054	303 41
v "	F ?	5.19	− .030	+ .05	0.058	210 58
χ^1 "	A ?	5.36	− .015	+ .03	0.033	206 34
51 "	A	5.25	− .030	.....	0.030	270 0
52 "	A	4.60	+ .030	− .02	0.036	56 19
$\varkappa$ Aquilæ	A ?	5.20	− .015	.....	0.015	270 0
42 Aquilæ	F ?	5.73	+ .150	+ .09	0.175	120 58
53 Sagittarii	A	5.43	+ .075	− .11	0.133	214 19
Bradley 2488	H	6.03	+ .075	− .09	0.117	219 48

There are 43 stars in all, 21 of which have their angles of direction in the third quadrant. The following table analyses these 21 stars into their respective classes, and gives the mean angle of direction for each class after rejection of spectra:

Spec.	Number of Stars.		Mean Direction rejecting ?		Mean Direction for all.
A	3	2 ?	242°	04′	225° 35′
E	1		252	28	
F	3	2 ?			
H	5	1 ?	237	43	
K	3	1 ?	203	01	

The direction of Class K is most nearly parallel to the commonly accepted direction of the Sun's way (here = 180° about),

though still manifesting considerable S. W. bias, a bias rendered most evident by Class F.

In short, there exists in this region, already interesting from the large preponderance of second-type stars congregated here, a distinct drift in a direction between 203° and 252°, and, moreover, one which may be called a drift against the stream; for if the Sun's goal be located at XVII^h ±, these stars, if fixed, should obtain parallactic motions in increasing R. A. and N. P. D., placing their angles of direction in the second quadrant, a very little removed from 180°. The distribution of the angles of direction in the four quadrants, however, is shown in the following table:

Spec.	0° — 90°		90° — 180°		180° — 270°		270° — 360°
A	4	2?	1	1?	4	2?	1
B	1						
EF	1			2?	6	1?	
H	3				5	1?	1
I			1				
K			1		3	1	
	9	2?	3	3?	18	5?	2

From this it appears that the general drift is in the third quadrant, counter to the parallactic motion in right ascension, though conforming to it in N. P. D. The first quadrant shows the greatest number of apparent exceptions, but when the angles of direction in this quadrant are compared with those in the third quadrant, some suggestive results are obtained.

Thus the angle of direction of the F star Piazzi XVIII 225 is 74° ±. Now the angle for Bradley 2319, an E star a few degrees removed, is 254° ±. Consequently there exists a difference of exactly 180° between the angles of direction of proper motion in these two stars. Whilst the other members of Classes E, F have with one other exception in R. A. motions in diminishing R. A. and increasing N.P.D., Piazzi XVIII 225 has opposite signs in both ocordinates. There would appear to be small doubt that it is in reality travelling in the same absolute direction as its compeers, but owing to its smaller westerly motion, the latter is reversed and rendered easterly by the parallactic motion imposed upon it by the solar advance, whilst possessing a relatively larger northerly motion, it still retains a residue of its real motion in that direction even after having been discounted by parallactic motion.

Other instances in the same order of ideas are furnished by μ^1 Sagittarii (F) and ν^1 Sagittarii (H), which have a common proper motion of 0″.61 per an. in direction 260° 33′, whilst φ

Sagittarii (A) with reversed signs travels at an angle of 80° 33′ (260° 33′ — 180°). 2 Aquilæ (F) moves in the direction 236° 19′, 52 Sagittarii (A) towards 56° 19′ (236° 19′ — 180°); Bradley 2313 (A), 180°; Bradley 2314 (A), 0°. ξ^1 Sagittarii (A) 90°, 51 Sagittarii (A) and κ Aquilæ (A?), 270°; and so on.

Further it will be seen that angles of direction in the first and third, and second and fourth quadrants respectively, may be paired within a few degrees by the method + or — 180°, and as a result, the apparent motions in opposite quadrants are reduced to a fundamental line of motion underlying them, the task remaining to determine in which direction on this line the real motion takes place.

In the present instance we have (see table) a preponderance of outstanding motions in diminishing R. A., despite the fact that motion in such a direction must have been already curtailed by the parallactic motion resulting from the solar advance towards $XVII^h \pm$.

Spectrum.	Diminishing R. A.	Average.	Increasing R. A.	Average.
A	5	0″.036	8	0″.054
EF	5	0 .102	3	0 .045
H	7	0 .060	4	0 .086
IK	4	0 .184	2	0 .015
	Average for all = — 0 .088			+ 0 .056

The angles of direction of the stars with diminishing R. A. must therefore be nearer approximations to the absolute direction than those of the stars whose motions are exceeded, and consequently reversed and disguised by parallactic motion.

When we examine the motions in N.P.D., parallactic motion is in the ascendant, 26 stars having increasing, and 12 only diminishing N.P.D., 5 being neutral. The two sets are made up as shown in the following table:

Spectrum.	Increasing N.P.D.	Average.	Diminishing N.P.D.	Average.
A	5	0″.034	6	0″.045
B	1	0 .080	0	.....
EF	9	0 .038	1	0 .030
H	5	0 .092	5	0 .036
IK	6	0 .228	0	.....
	Average for all = + 0 .093			— 0 .040

Despite the extent to which parallactic motion here tells in increasing N.P.D., there remain 12 stars which are able to pay the toll exacted by it, and still pursue, though warped to some degree, the direction of their original motions. Nevertheless, they do not suffer absolute parallactic reversal as would appear to be the case with the 18 stars with increasing N.P.D.

XUM

Now remembering that counter to the direction of parallactic motion, 21 stars move in diminishing R. A. against 17 in increasing R. A.; and noting here that 12 stars emerge from the influence of the same cause with unreversed motions in diminishing N.P.D. and further, calling to mind the cases of motion executed on the same line in opposite quadrants and at identically opposite angles; it would appear that this remarkable congeries of stars has a true drift in the direction of diminishing R. A. and diminishing N.P.D., consequently with its goal in that quadrant in which the solar apex is located.

It will be noticed that stars of Type I follow the fortunes of the group without parting company in any way with those of Type II, and exhibit the distinctive features of diminishing R. A. and N.P.D. with equal clearness.

Further, the charts give evidence of a general correspondence in magnitude in stars of Types I and II located in the same parts of the heavens. Thus in passing from Cassiopeia to Camelus, we pass from a region of relatively large magnitudes in both first and second type stars, to one where both types suffer a common diminution in magnitude. Another equally obvious example is furnished by an aggregation of some 150 faint stars upon the line of division between the constellations Lyra and Hercules. Here A, E, F and H stars contribute to the formation of a cluster equally distinguished from surrounding stars by the condensation and faintness of its constituents. Again, comparison of circumpolar regions with those at the equator, shows that the former contain stars about one magnitude fainter than the latter. These faint circumpolar stars are very numerous, and Types I and II are alike laid under contribution to furnish them, whilst their exclusion from the equatorial zones is equally operative for both types.

A further refinement in the same line of research is presented by the investigation of the polytypic or monotypic, multispecial or unispecial nature of star-streams. By polytypic and monotypic I would define streams composed of one or more of the great types; and by unispecial and multispecial, streams composed of one or more classes of the same type.

That star-streams exist, a short study of any stellar photograph will testify; still, the difficulties are great, and must in many cases be insuperable, in the reliable identification of the members of a star-stream at such limits of magnitude as shall leave any certainty as to the correct reading of the spectrum. Special difficulties, moreover, present themselves in deciphering

composite streams, absolute isolation of the stream seeming the only sufficient guarantee of genuineness in polytypic streams, and isolation from stars of the same type a necessary criterion in the case of multispecial streams. But as streams only become apparent in the lower magnitudes, and consequently with increasing numbers, isolation is rendered well nigh impossible.

In fact the difficulties are such that the problem of the existence of polytypic and multispecial streams is reserved for discussion with the proper motions.

On the other hand, the charts afford ample evidence of the existence of unispecial streams. A notable instance, though by no means uniquely so, occurs where the equator cuts the galaxy in Monoceros. Of some 300 stars included between V^h 30^m and VI^h 30^m in R. A., and + 15° to — 30° in Decl., 45 are of classes H, I and K, though I and K are only represented by some three or four stars, generally of larger magnitude. These 45 stars have been all faithfully charted in the accompanying small map. Specially referring to the large S-shaped curve extending from + 9° to — 15°, it would seem that such a perfection in the curve could not possibly be attained by a chance distribution of its components. When it is stated, moreover, that this curve is projected upon a background of some 250 stars of other type and classes in undecipherable confusion, and that the latter, in the condensation about the track of the curve itself, are as 10 to 1, there can surely remain no doubt as to the genuineness of this, and of other curves existing under like conditions. Its isolation, whilst facilitating its recognition, likewise confirms its genuineness. How far the stream continues south can only be seen when the Arequipa results are made known.

Curves of the above description exist in all parts of the charts, and the general equality of magnitude and of the intervals separating the components, together with the regularity with which they are disposed along the curve, and the persistence with which the latter often develops through irregular groupings of stars of other types, would seem to place the existence of unispecial curves and streams beyond question.

There is an interesting feature in connection with these H curves, viz: the terminal stars are very often K stars, though an M star will likewise frequently be found in a similar position in an H curve. These peculiarities are exemplified by the curve given. Betelgeuse is an M star; 5 Monocerotis at the bend is a K, the star at VI^h 35^m R. A., — 14° 3′ is an I star.

As it is not the object of the present paper to examine into the

proper motions in any other than a general manner, leaving the detailed examination of special districts for later attention, a general survey only of the relations of large proper motion existing among the various classes of spectra will be now attempted, with a view of disclosing points of sympathy and contrast which it is the present purpose to accentuate.

By collating Bossert's Catalogue of Proper Motions above 0″.50 with the D. C., upwards of a hundred stars were identified, and they are classified according to spectrum and amount of annual displacement in the following table:

Spec.	Above 5″	Above 4″	Above 3″	Above 2″	Above 1″.50	Above 1″.0	Above 0″.75	Above 0″.50	Total	Average. With ? ″	Average. Without ? ″
A	1 ?	...	...	...	...	... 1 ?	1 2 ?	6 1 ?	7 5 ?	0.70	0.65*
E	...	...	...	...	...	3	1 2 ?	3 2 ?	7 4 ?	0.74	0.82
F	...	...	...	...	...	8	6	19 1 ?	33 1 ?	0.77	0.78
G	...	...	...	...	1 ?	...	1	2	3 1 ?	1.02	0.72
H	1	1 ?	1	2	1 ...	2 1 ?	2	13	22 2 ?	1.34	1.23
I	...	..	...	...	1 ?	1	2 1 ?	4 1 ?	7 3 ?	0.85	0.70
K	...	...	...	1	...	1	3	1 1 ?	6 1 ?	1.03	1.11†
M	...	...	...	...	...	...	...	1	1	.....	.....

* Omitting 1830 Groombridge. † Without Arcturus = 0″.87.

From the above it will be seen that though class F is superior to any other as to the number of stars having proper motions above 0″.50, class H is superior to class F as possessing the largest number of stars with largest proper motion. The results are also interesting as showing that no class of any numerical importance save B is without representatives with large proper motion, the star with the largest proper motion in class B being ξ Ophiuchi with an annual displacement of 0″.32. This is very much in excess of the average proper motion of class B, which is about 0″.05.

An examination of the spectra of binary systems of assignable period appears to offer reliable data as to their distances, and consequently, distribution, for the fact that the components of a binary of moderate period are separable renders it probable that they are situated at distances less than those of stars whose slow revolution does not admit of their period being defined. If not, then the increased speed of revolution must be the result of incomparably greater masses or relatively minute distances of separation between the components. But if the former, we run into extremes; if the latter, the obvious effect of the reduction of the distance of separation between the components would be to render them inseparable in the telescope.

Of a list of 46 binaries compiled by Mr. Gore, I was able to identify those of the following table, which shows the distribution among the several classes of spectra:

Spectrum	A	B	E	F	G	H	K	M
	7	1	2	9	3	1	2	1
	1?	...	...	3?	...	2?	...	...

Here again class F is numerically superior; still class A, and even the small classes B and M, are able to furnish testimony to the solidarity of the stellar concourse, no class being so far withdrawn into space but some representative binary stamps it as a denizen of regions not incomparably remote from those occupied by its fellow binaries.

Further corroboration of the mixed state of society prevailing among the stars is derivable from the spectra of stars with observed parallax. The following table, put together from the list of parallaxes given in Miss A. M. Clerke's "System of the Stars," distributes them in their classes, and gives the average parallax per class:

Spectrum	A	E	F	H	K	M
	5	1	9	6	6	1
	6?	...	...	1?	4?	...
Average with ?	0″.172	...	...	0″.210	0″.141	...
Average without ?	0″.127	0″.054	0″.122	0″.217	0″.104	0″.027

Again there is no feature either in amount of parallax or number of stars involved differentiating one type decisively from another, though among the classes H manifests a superiority in the amount of parallactic displacement in accord with its greater proper motions.

A chart constructed to show at once the motions of approach and recession of Vogel's 51 stars, and the amount and direction of their proper motions, brought out further instances of sympathetic variation in the two great types. These stars are all of large magnitude and the list is made up as shown in the following table, which gives also the average tangential and radial motion for each class:

	A	B	F	G	K	L	M	Q
	25	2	6	1	12	1	2	2 = 51
Tang.	0″.258	0″.046	0″.394	0″.076	0″.425*	0″.153	0″.128	0″.071 per annum.
Rad.	12	3.2	9.46	10.1	11.08†	8.9	7.4	3.1 miles per second.

* Without Arcturus (2″.280) = 0″.257. † Without Aldebaran (+ 30.2) = 10.1 miles per second.

From an inspection of this chart it was evident that the 51 stars fall into natural groups, the members of which are associated by proximity on the sphere or relationship in tangential and radial motion as to direction and amount. It is seldom that three, if not four of these criteria fail to be satisfied by the members of a group. The groups themselves are made up as detailed below:

Group I.

$XX^h - I^h$ R. A.

α Cygni	A	−5.0	−0.43	0.38
γ "	O	−4.0		
α Pegasi	A	+0.8	+0.37	
β "	M?	+4.1		
ϵ "	K	+5.0		
α Androm.	A	+2.8		
β "	K	+7.0		
β Cass.	F	+3.2		

Group II.

$I^h - IV^h$ R. A.

α Cassiopeia	K	−9.5	−0.86
γ "	O	−2.2	
α Ursæ Minoris	F	−16.1	
γ Andromedæ	K	−8.0	
α Arietis	K	−9.2	
α Persei	F	−6.4	
β "	A	−11.0	

Group III.

$IV^h - VI^h$ R. A.

α Tauri	K?	+30.2	+1.10
α Aurigæ	F	+15.2	
β Orionis	F	+10.2	
γ "	B	+5.7	
β Tauri	A	+5.0	
δ Orionis	B	+0.6	
ϵ "	A	+16.5	
ζ "	A	+9.3	
α "	M?	+10.7	

Group IV.

$VI^h - VIII^h$ R. A.

β Aurigæ	A	−17.5	−1.20
γ Geminorum	A	−10.3	
α Canis Majoris	A?	−9.8	
α Geminorum	A	−18.4	
α Canis Minoris	F	−5.7	

$VIII^h - X^h$ R. A.

No Stars.

Group V.

$X^h - XV^h$ R. A.

α Leonis	A	−5.7	−1.30
β "	A	−7.6	
γ "	K	−24.0	
δ "	A	−8.9	
α Ursæ Majoris	K	−7.2	
β "	A	−18.2	
γ "	A	−16.5	
ϵ "	A	−18.8	
ζ "	A	−19.4	
η "	A	−16.3	
α Virginis	A	−9.2	
α Boötis	K	−4.8	
ϵ "	G?	−10.1	
β Libræ	A	−6.0	
β Herculis	K	−22.0	

Group VI.

$XV^h - XVIII^h$ R. A.

β Ursæ Minoris	L?	+8.9	+1.30
α Coronæ	A	+19.7	
α Serpentis	K?	+14.0	
α Ophiuchi	A	+11.9	

Group VII.

$XVIII^h - XX^h$ R. A.

α Lyræ	A	−9.5	−1.56
α Aquilæ	A	−22.9	

The averages have been obtained by dividing the average radial velocity per group by the general average radial velocity for all = 10.4 miles per second.

β Geminorum has been omitted, almost the whole of its motion being on the tangent.

It will be seen that the groups are all polytypic save Gr. VII; consequently the variation in direction and amount of radial motion from group to group affects all types included in the group.

Further remarkable features are brought to light by this chart, to which I may be permitted to advert *en passant*. Thus the district XX^h—IV^h R. A. is one of small motions, smallest between XX^h—$XXIV^h$ $30^m \pm$, where they are mostly of approach, and somewhat larger between $XXIV^h$ $30^m \pm$ —IV^h R. A., where they

are almost exclusively of recession. Opposite to this region is a district of equal area, say $VIII^h - XV^h \pm$ R. A., in which uniform and large motion of recession takes place.

Separating these two great districts, of which the central meridians are roughly 0^h and XII^h R. A., are two others from IV^h—$VIII^h$ on the one side of the hemisphere, and from XV^h—XX^h on the other. These are again divisible into two parts each. IV^h—VI^h R. A. contains the large motions of approach of Group III: opposite to this region, XV^h—$XVIII^h$ R. A. contains the large motions of approach of Group VI. The region VI^h—$VIII^h$ R. A. is occupied by the large motions of recession of Group IV; and the region opposite $XVIII^h$— XX^h R. A., by the large motions of recession of Group VII.

With the view of rendering more evident the solidarity of the universe, I have now passed in review evidence drawn from the following sources:— sympathetic variation in the curves of distribution of the great types, sympathetic variation in magnitude, community of drift, similarity in the possession of large proper motion, telescopic separability of binaries of assigned period, common subjection to parallactic displacement, concurrent variation in radial velocities both as to direction and amount. On the other hand, and under restrictions almost prohibitive, I have failed up to the present to discover polytypic and multispecial curves; unspecial curves, however, were found to be numerous.

STRETFORD, Lancs., October 27, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

The Ultra-red Spectra of the Alkalies.—In a recent number of Wieldemann's *Annalen* (No. 10, 1892), Mr. B. N. Snow describes some investigations concerning the ultra-red spectra of the Alkalies. The object of the work was to learn if the ultra-red "lines" belonged to continuations of the series of visible lines so carefully studied by Kayser and Runge. Mr. Snow used a prism spectroscope and a bolometer, and his observations seem to be consistent and accurate. Of course, the test of a line's belonging to a given series is a physical one, not a mathematical one, and the most obvious physical property to observe in the method used was the intensity. But of all the properties of a line, especially an invisible one, this is the most difficult to measure. Mr. Snow realized the difficulties of the problem, and overcame them as best he could. The result of his

investigations is to show that, except in the case of sodium and lithium, the ultra-red "lines" do not form part of the visible series. He does not seem, though, to have studied the lines themselves independently, to see if they formed separate series. This last suggestion would appear the more plausible judging from all analogies.

Unusual Appearance in a Sun-Spot.—We have received from Miss E. Brown a sketch of the anomalous facula observed in a Sun-spot on Aug. 21, and noted in our last number. In her letter she adds, "On Nov. 10 (1892) 1.15, G. M. T, I observed a similar patch of faculous light between the umbra and penumbra of a Sun-spot in Long. 296°, Lat. 22° N. It was of very much smaller proportions and equally evanescent, having disappeared in less than three hours."

From these various appearances it is evident that the Sun should be much more constantly observed than is now the case. Amateurs with telescopes of any aperture would do well to enter this fruitful and interesting field. Even the smallest telescopes will suffice for the work, and the method of observing the Sun's image projected on a screen of white paper will be found most effective.

The Sun's Effect on Terrestrial Magnetism.—We wish to call attention to the following very important considerations presented by Lord Kelvin in his recent Presidential Address to the Royal Society, and printed in *Nature* for Dec. 1, 1892.

"Guided by Maxwell's "electro-magnetic theory of light," and the undulatory theory of propagation of magnetic force which it includes, we might hope to perfectly overcome a fifty years' outstanding difficulty in the way of believing the Sun to be the direct cause of magnetic storms in the Earth, though hitherto every effort in this direction has been disappointing. This difficulty is clearly stated by Professor W. G. Adams, in the following sentences, which I quote from his Report to the British Association of 1881 (p. 469) "On Magnetic Disturbances and Earth Currents:"—"Thus we see that the magnetic changes which take place at various points of the Earth's surface at the same instant are so large as to be quite comparable with the Earth's total magnetic force; and in order that any cause may be a true and sufficient one, it must be capable of producing these changes rapidly."

"The primary difficulty, in fact, is to imagine the Sun a variable magnet or electro-magnet, powerful enough to produce at the Earth's distance changes of magnetic force amounting, in extreme cases, to as much as one-twentieth or one-thirtieth, and frequently, in ordinary magnetic storms, to as much as one four-hundredth of the undisturbed terrestrial magnetic force.

"The Earth's distance from the Sun is 228 times the Sun's radius, and the cube of this number is about 12,000,000. Hence, if the Sun were, as Gilbert found the Earth to be, a globular magnet, and if it were of the same average intensity of magnetization as the Earth, we see, according to the known law of magnetic force at a distance, that the magnetic force due to the Sun at the Earth's distance from it, in any direction, would be only a twelve-millionth of the actual force of terrestrial magnetization at any point of the Earth's surface in a corresponding position relatively to the magnetic axis. Hence the Sun must be a magnet* of not much short of 12,000 times the average intensity of the terrestrial magnet (a not absolutely inconceivable supposition, as we shall presently see) to produce,

* The Moon's apparent diameter being always nearly the same as the Sun's, the statements of the last four sentences are applicable to the Moon as well as to the Sun, and are important in connection with speculation as to the cause of the lunar disturbance of terrestrial magnetism, discovered nearly fifty years ago by Kreil and Sabine.

by direct action simply as a magnet, any disturbance of terrestrial magnetic force sensible to the instruments of our magnetic observatories.

"Considering probabilities and possibilities as to the history of the Earth from its beginning to the present time, I find it unimaginable but that terrestrial magnetism is due to the greatness and the rotation of the Earth. If it is true that terrestrial magnetism is a necessary consequence of the magnitude and the rotation of the Earth, other bodies comparable in these qualities with the Earth, and comparable also with the Earth in respect to material and temperature, such as Venus and Mars, must be magnets comparable in strength with the terrestrial magnet, and they must have poles similar to the Earth's north and south poles on the north and south sides of their equators, because their directions of rotation, as seen from the north side of the ecliptic, are the same as that of the earth. It seems probable, also, that the Sun, because of its great mass and its rotation in the same direction as the Earth's rotation, is a magnet with polarities on the north and south sides of its equator, similar to the terrestrial northern and southern magnetic polarities. As the Sun's equatorial surface-velocity is nearly four and a half times the Earth's, it seems probable that the average solar magnetic moment exceeds the terrestrial considerably more than according to the proportion of bulk. Absolutely ignorant as we are regarding the effect of cold solid rotating bodies such as the Earth, or Mars, or Venus, or of hot fluid rotating bodies such as the Sun, in straining the circumambient ether, we cannot say that the Sun might not be 1000, or 10,000, or 100,000 times as intense a magnet as the Earth. It is, therefore, a perfectly proper object for investigation to find whether there is, or is not, any disturbance of terrestrial magnetism, such as might be produced by a constant magnet in the Sun's place with its magnetic axis coincident with the Sun's axis of rotation. Neglecting for the present the seven degrees of obliquity of the Sun's equator, and supposing the axis to be exactly perpendicular to the ecliptic, we have an exceedingly simple case of magnetic action to be considered: a magnetic force perpendicular to the ecliptic at every part of the Earth's orbit and varying inversely as the cube of the Earth's distance from the Sun. The components of this force parallel and perpendicular to the Earth's axis are, respectively, 0.92 and 0.4 of the whole; of which the former could only be perceived in virtue of the varying distance of the Earth from the Sun in the course of a year; while the latter would give rise to a daily variation, the same as would be observed if the red ends of terrestrial magnetic needles were attracted towards an ideal star of declination 0° and right ascension 270°. Hence, to discover the disturbances of terrestrial magnetism, if any there are, which are due to direct action of the Sun as a magnet, the photographic curves of the three magnetic elements given by each observatory should be analysed for the simple harmonic constituent of annual period and the simple harmonic constituent of period equal to the sidereal day. We thus have two very simple problems, each of which may be treated with great ease separately by a much simplified application of the principles on which Schuster has treated his much more complex subject, according to Gauss' theory as to the external or internal origin of the disturbance, and Professor Horace Lamb's investigation of electric currents induced in the interior of a globe by a varying external magnet. The sidereal diurnal constituent which forms the subject of the second of these simplified problems is smaller, but not much smaller, than the solar diurnal term which, with the solar semi-diurnal, the solar ter-diurnal, the solar quarter-diurnal constituents form the subjects of Schuster's paper. The conclusion at which he has arrived, that the source of the disturbance is external, is surely an ample reward for the great labor he has be-

stowed on the investigation hitherto; and I hope he may be induced to undertake the comparatively slight extension of his work which will be required for the separate treatment of the two problems of the sidereal diurnal and the solar annual constituents, and to answer for each the question:—Is the source external or internal?

"But even though external be the answer found in each case, we must not from this alone assume that the cause is direct action of the Sun as a magnet. The largeness of the solar semi-diurnal, ter-diurnal, and quarter-diurnal constituents found by the harmonic analysis, none of which could be explained by the direct action of the Sun as a magnet, demonstrate relatively large action of some other external influence, possibly the electric currents in our atmosphere, which Schuster suggested as a probable cause. The cause, whatever it may be, for the semi-diurnal and higher constituents would also probably have a variation in the solar diurnal period on account of the difference of temperature of night and day, and a sidereal and annual period on account of the difference of temperature between winter and summer.

Even if, what does not seem very probable, we are to be led by the analysis to believe that magnetic force of the Sun is directly perceptible here on the Earth, we are quite certain that this steady force is vastly less in amount than the abruptly varying force which, from the time of my ancestor in the Presidential Chair, Sir Edward Sabine's discovery,* forty years ago, of an apparent connection between Sunspots and terrestrial magnetic storms, we have been almost compelled to attribute to disturbing action of some kind at the Sun's surface.

"As one of the first evidences of this belief, I may quote the following remarkable sentences from Lord Armstrong's Presidential Address to the British Association at Newcastle, in 1863:—

'"The sympathy also which appears to exist between forces operating in the Sun and magnetic forces belonging to the Earth merits a continuance of that close attention which it has already received from the British Association, and of labors such as General Sabine has, with so much ability and effect, devoted to the elucidation of the subject. I may here notice that most remarkable phenomenon which was seen by independent observers at two different places, on September 1, 1859. A sudden outburst of light, far exceeding the brightness of the Sun's surface, was seen to take place, and sweep like a drifting cloud over a portion of the solar face. This was attended with magnetic disturbances of unusual intensity, and with exhibitions of aurora of extraordinary brilliancy. The identical instant at which the effusion of light was observed was recorded by an abrupt and strongly-marked deflection in the self-registering instrument at Kew. The phenomenon as seen was probably only part of what actually took place, for the magnetic storm in the midst of which it occurred commenced before, and continued after the event. If conjecture be allowable in such a case, we may suppose that this remarkable event had some connection with the means by which the Sun's heat is renovated. It is a reasonable supposition that the Sun was at that time in the act of receiving a more than usual accession of new energy; and the theory which assigns the maintenance of its power to cosmical matter, plunging into it with that prodigious velocity which gravitation would impress upon it as it approached to actual contact with the solar orb, would afford an explanation of this sudden exhibition of intensified light, in harmony with the knowledge we have now attained, that arrested motion is represented by equivalent heat."

"It has certainly been a very tempting hypothesis, that quantities of meteoric

* Communication to the Royal Society, March 18, 1852 (*Phil. Trans.*, vol. clxii, p. 143.)

matter suddenly falling into the Sun is the cause, or one of the causes, of those disturbances to which magnetic storms on the Earth are due. We may, indeed, knowing that meteorites do fall into the Earth, assume without doubt that much more of them fall, in the same time, into the Sun. Astronomical reasons, however, led me long ago to conclude that their quantity annually, or per century, or per thousand years, is much too small to supply the energy given out by the Sun in heat and light radiated through space, and led me to adopt unqualifiedly Helmholtz's theory, that work done by gravitation on the shrinking mass is the true source of the Sun's heat, as given out at present, and has been so for several hundred thousand years, or several million years. It is just possible, however, that the outburst of brightness described by Lord Armstrong may have been due to an extraordinarily great and sudden falling in of meteoric matter, whether direct from extra-planetary space, or from orbital circulation round the Sun. But it seems to me much more probable that it was due to a refreshed brightness produced over a larger area of the surface than usual by brilliantly incandescent fluid rushing up from below, to take the place of matter falling down from the surface, in consequence of being cooled in the regular *regime* of solar radiation. It seems, indeed, very improbable that meteors fall in at any time to the Sun in sufficient quantity to produce dynamical disturbances at his surface at all comparable with the gigantic storms actually produced by hot fluid rushing up from below, and spreading out over the Sun's surface.

"But now let us consider for a moment the work which must be done at the Sun to produce a terrestrial magnetic storm. Take, for example, the magnetic storm of June 25, 1885, of which Adams gives particulars in his paper of June, 1891 (*Phil. Trans.* p. 139, and Pl. 9). We find at eleven places, St. Petersburg, Stonyhurst, Wilhelmshaven, Utrecht, Kew, Vienna, Lisbon, San Fernando, Colaba, Batavia and Melbourne, the horizontal force increased largely from 2 to 2:10 P. M., and fell at all the places from 2:10 to 3 P. M., with some rough ups and downs in the interval. The storm lasted altogether from about noon to 8 P. M. At St. Petersburg, Stonyhurst and Wilhelmshaven, the horizontal force was above bar py 0.00075, 0.00088, and 0.00090 (C.G.S. in each case) at 2:10 P. M.; and below par by 0.0007, 0.00066, 0.00075 at 3 o'clock. The mean value for all the eleven places was nearly 0.0005 above par at $2^h\ 10^m$, and 0.0005 below par at 3^h. The photographic curves show changes of somewhat similar amounts following one another very irregularly, but with perfectly simultaneous correspondence at the eleven different stations, through the whole eight hours of the storm. To produce such changes as these by any possible dynamical action within the Sun, or in his atmosphere, the agent must have worked at something like 160 million million million million horse-power* (12×10^{35} ergs per sec.), which is about 364 times the total horse power (3.3×10^{33} ergs per sec.) of the solar radiation. Thus, in this eight hours of a not very severe magnetic storm, as much work must have been done by the Sun in sending magnetic waves out in all directions through space as he actually does in four months of his regular heat and light. This result, it seems to me, is absolutely conclusive against the supposition that terrestrial magnetic storms are due to magnetic action of the Sun; or to any kind of dynamical action taking place within the Sun, or in connection with hurricanes in his atmosphere, or anywhere near the Sun outside.

"It seems as if we may also be forced to conclude that the supposed connection between magnetic storms and Sunspots is unreal, and that the seeming agreement between the periods has been a mere coincidence.

* 1 horse-power = 7.46×10^9 ergs per sec.

XUM

"We are certainly far from having any reasonable explanation of any of the magnetic phenomena of the earth; whether the fact that the Earth is a magnet; that its magnetism changes vastly, as it does from century to century; that it has somewhat regular and periodic annual, solar diurnal, lunar diurnal, and sidereal diurnal variations; and (as marvelous as the secular variation) that it is subject to magnetic storms. The more marvellous, and, for the present inexplicable, all these subjects are, the more exciting becomes the pursuit of investigations which must, sooner or later, reward those who persevere in the work. We have at present two good and sure connections between magnetic storms and other phenomena: the aurora above, and the earth currents below, are certainly in full working sympathy with magnetic storms. In this respect the latter part of Mr. Ellis's paper is of special interest, and it is to be hoped that the Greenwich observations of Earth currents will be brought thoroughly into relation with the theory of Schuster and Lamb, extended, as indeed Professor Schuster promised to extend it, to include not merely the periodic diurnal variations, but the irregular sudden changes of magnetic force taking place within any short time of a magnetic storm."

The Astronomical Congress at Chicago in 1893.—Preparations for an International Congress embracing Mathematics, Astronomy and Astro-Physics, to be held in connection with the Columbian Exposition, are going rapidly forward, and the invitations will soon be sent out. The general Congress will convene on August 21, 1893, and afterwards separate into three sections. The local committee is constituted as follows:

GENERAL COMMITTEE.

Professor George W. Hough, Chairman.

Mr. S. W Burnham, Vice-Chairman.

SECTIONAL COMMITTEES.

Mathematics: Professor E. W. Moore, Chairman; Professor E. S. White, Professor Oskar Bolza, Professor Heinrich Maschke.

Astronomy: Professor G. W. Hough, Chairman: Mr. S. W. Burnham, Professor Malcolm McNeill, Professor G. C. Comstock, Professor W. W. Payne, Mr. G. A. Douglass, Mr. R. W. Pike.

Astro-Physics: Professor G. E. Hale, Chairman; Professor Henry Crew, Professor C. B. Thwing.

Errata.—In Professor Campbell's article in ASTRONOMY AND ASTRO-PHYSICS, November, 1892, pp. 807, 808, columns 3 and 6, the *periods* followed by two decimals should be *hyphens* followed by the third and fourth places of tenth-metres. Thus 5456.47 really means the group of lines 5456, 5447, and for brevity it was intended to be written 5456-47. In plate XL accompanying the same article, the letter C over the spectrum has been transformed by the reproducer into an O.

On the History of the Bolometer.—At a time when so many men are at work in each department of experimental science an undisputed discovery appears to be the exception rather than the rule. This is notably true of useful electrical devices. Claims of priority are so often well-based, and again so often ill-founded, that one finds it difficult to decide upon them according to any general rule.

On the one hand, the crop of astronomers (?) that have seen the Fifth Satellite of Jupiter before Barnard is easily disposed of; while, on the other hand, one is confronted with such genuine double discoveries as those of Lockyer and Janssen, Gray and Bell, Leverrier and Adams.

XUM

But between these two extremes, one meets many cases in which it is not easy to say whose is the priority, or even then, whose the honor.

A case of this kind was presented, by Mr. Kurlbaum, to the Physical Society of Berlin at its session of Jan. 8th, 1892.

It was here set forth that the bolometer was devised by Soanberg in 1851, some thirty years before Langley's work with it.

We have taken occasion to read Soanberg's* description of his Differential Thermometer, and it leaves no doubt whatever that he employed a Wheatstone's Bridge in essentially the same manner, and for essentially the same purpose as Langley.

For instance, Soanberg used an astatic galvanometer which would indicate differences of temperature amounting to no more than 1/650° C. He also used lamp black on that arm of the bridge whose variation in resistance was to indicate variation of temperature. In short the priority is Soanberg's.

But, as everybody knows, Prof. Langley is the man who has given the bolometer "a local habitation and a name."

He it was who recognized the adaptability of the instrument, and the tremendous importance of the work it was capable of doing, and who did the work, spending presumably more than nine tenths of his time in avoiding a thousand and one difficulties of which the uninitiated know nothing.

This remark is not intended as any eulogy on Prof. Langley, or as any detraction from the work of Soanberg, but merely as an expression of opinion that, in all such cases, original sources should be consulted, the facts ascertained as exactly as possible, and then care be used to see that *mere* antecedence does not come into the balance against development of a new method and results obtained.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR FEBRUARY.

Mercury will be at superior conjunction Feb. 16, and will therefore not be visible during this month.

Venus rises only an hour earlier than the Sun during February, and is therefore not in good position for observation.

Mars will be visible during the early part of the evening, but his distance will be so great as to make observations of the surface markings unsatisfactory. Mars will be in conjunction with the Moon Feb. 21 at 8^h A. M. central time. There will be an occultation of the planet as seen from the equatorial regions of the other side of the Earth.

Jupiter will also be visible in the early morning during February, the two planets, Jupiter and Mars, being in the same region of the sky towards the southwest. There will be an occultation of Jupiter by the Moon Feb. 20 at about 9 A. M. central time. It will be visible in Asia.

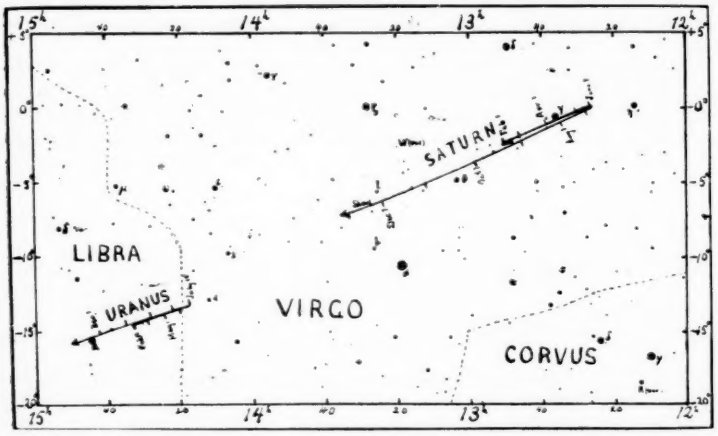
From *The Observatory* for December, 1892, we have the following ephemeris of the fifth satellite of Jupiter by Mr. A. Marth:

---

* *Soanberg* (*A. F.*): Ueber Messung des Leitungs-wiederstands für Electrische Ströme und über ein galvanisches Differential-thermometer. Pogg. Ann. Bd. 84, pp. 411–418.

	Central Time of Greatest Elongation. East.	Distance from Planet's Center. West.
	h m	h m ″
1893 Jan. 10	4 00 P. M.	9 58 P. M. 51
20	3 00 "	9 09 " 49
30	2 22 "	8 20 " 48

Saturn rises at about 10 P. M. on Feb. 1, and will be in good position for observation after midnight. The accompanying chart will indicate where to look for the planet. The constellation Virgo at midnight Feb. 1 will be a little south of east and about half way from the horizon to the zenith. The planet is now moving very slowly eastward in the center of the constellation but will soon turn westward, making the loop indicated on the chart, until June 9, when it will again take up its journey to the east. The plane of the rings now makes an angle of about 9° with the line of sight, so that the rings may be distinctly seen. Saturn will be in conjunction with the Moon, 1° 02′ north, Feb. 5 at $11^h\ 16^m$ A. M. central time.



Uranus is a little farther to the east than Saturn. His path for this year is shown on the accompanying chart with that of Saturn. It will be noticed that the planet is almost on a direct line between the stars α Libræ and λ Virginis. Uranus will be stationary Feb. 13, and after that move westward until July 14, when he will turn on his course and continue direct motion toward the east for the remainder of the year. There will be a conjunction of Uranus with the moon Feb. 9 at $7^h\ 29^m$ P. M., the former being 1° 22′ north of the latter.

Neptune will be stationary in Taurus Feb. 17 at $5^h\ 16^m$ A. M., and will after that move slowly eastward. For chart of his path see Dec., 1892, number of this journal, p. 937.

MERCURY.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Feb. 5.....	20 48.3	− 19 55	7 03 A. M.	11 43.7 A. M.	4 24 P. M.
15.....	21 57.7	− 14 35	7 09 "	12 13.7 P. M.	5 18 "
25.....	23 07.3	− 6 55	7 08 "	12 43.8 "	6 20 "

VENUS.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Feb. 5.....	19 51.3	− 21 17	6 13 A. M.	10 47.2 A. M.	3 21 P. M.
15.....	20 43.5	− 18 53	6 14 "	10 59.8 "	3 45 "
25.....	21 33.9	− 15 34	6 11 "	11 10.8 "	4 11 "

MARS.

Feb. 5.....	1 37.3	+ 10 39	9 46 A. M.	4 32.2 P. M.	11 18 P. M.
15.....	2 02.4	+ 13 06	9 22 "	4 17.9 "	11 14 "
25.....	2 28.1	+ 15 24	8 57 "	4 04.2 "	11 12 "

JUPITER.

Feb. 5.....	1 16.8	+ 6 53	9 41 A. M.	4 11.7 P. M.	10 42 P. M.
15.....	1 23.3	+ 7 35	9 05 "	3 38.9 "	10 12 "
25.....	1 30.5	+ 8 20	8 29 "	3 06.7 "	9 44 "

SATURN.

Feb. 5.....	12 50.3	− 2 36	9 50 P. M.	3 43.2 A. M.	9 36 A. M.
15.....	12 49.0	− 2 26	9 09 "	3 02.6 "	8 56 "
25.....	12 47.2	− 2 12	8 27 "	2 21.5 "	8 16 "

URANUS.

Feb. 5.....	14 33.7	− 14 37	12 26 A. M.	5 30.3 A. M.	10 35 A. M.
15.....	14 33.8	− 14 37	11 43 P. M.	4 47.1 "	9 51 "
25.....	14 33.5	− 14 35	11 03 "	4 07.5 "	9 12 "

NEPTUNE.

Feb. 5.....	4 28.2	+ 20 12	11 54 A. M.	7 22.5 P. M.	2 51 A. M.
15.....	4 28.1	+ 20 12	11 15 "	6 43.1 "	2 12 "
25.....	4 28.2	+ 20 13	10 35 "	6 03.8 "	1 32 "

THE SUN.

Feb. 5.....	21 18.7	− 15 41	7 14 A. M.	12 14.3 P. M.	5 15 P. M.
15.....	21 58.2	− 12 24	7 00 "	12 14.3 "	5 29 "
25.....	22 36.5	− 8 48	6 44 "	12 13.1 "	5 42 "

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Feb. 2	B.A.C. 3837	6.3	18 56	118	19 55	305	0 59
7	B.A.C. 4896	6.6	13 31	81	13 21	343	0 50
18	4 Ceti	6.0	6 12	125	6 36	170	0 24
18	5 Ceti	6.0	6 26	115	6 58	181	0 32
18	B.A.C 5	5.7	6 40	81	7 34	217	0 54
20	54 Ceti	5.5	6 57	53	8 06	250	1 09
21	π Arietis	5.7	9 32	34	10 20	290	0 48
22	B. A.C 1189	6.0	10 54	85	11 51	255	0 57
24	136 Tauri	5.3	11 02	44	11 45	325	0 45
26	ω^1 Cancri	6.0	11 54	97	13 01	308	1 07
26	ω^2 Cancri	6.3	12 36	145	13 32	258	0 56

Configuration of Jupiter's Satellites at 8^h p. m. Central Time.

Feb.		Feb.		Feb.	
1	3 2 1 ○ 4	11	1 4 ○ 2 3	21	4 ○ 3 1 2
2	♌ 3 2 ○ 4	12	2 ○ 1 4 3	22	4 3 1 2 ○
3	4 3 ○ 1 2	13	1 ○ 3 4 ●	23	4 3 2 ○ 1
4	4 1 ○ 2 3	14	3 ○ 1 2 4	24	4 3 1 ○ 2
5	4 2 ○ 1 3	15	3 1 2 ○ 4	25	♌ 4 ○ 3 2
6	4 1 ○ 2 3	16	3 2 ○ 1 4	26	4 2 ○ 1 3
7	4 3 ○ 1 2	17	3 ○ 2 4 ●	27	4 1 2 ○ 3
8	4 3 2 1 ○	18	1 ○ 2 3 4	28	○ 3 1 2●
9	4 3 2 ○ 1	19	2 ○ 1 4 3		
10	4 3 ○ 1 2	20	1 4 2 ○ 3		

Phenomena of Jupiter's Satellites.

1893.	h	m				h	m			
Feb. 1	8	12	P. M.	I	Oc. Dis.	Feb. 14	8	34	P. M.	III	Sh. In.
2	5	20	"	I	Tr. In.	15	6	17	"	II	Sh. Eg.
	6	35	"	I	Sh. In.	17	6	41	"	I	Oc. Dis.
	7	35	"	I	Tr. Eg.	18	4	55	"	I	Sh. In.
	8	48	"	I	Sh. Eg.		6	05	"	I	Tr. Eg.
3	6	06	"	I	Ec. Re.		7	08	"	I	Sh. Eg.
7	6	30	"	III	Sh. Eg.	21	8	12	"	III	Tr. In.
9	7	20	"	I	Tr. In.	22	6	28	"	II	Sh. In.
	8	30	"	I	Sh. In.		6	55	"	II	Tr. Eg.
10	4	41	"	I	Oc. Dis.	25	5	51	"	I	Tr. In.
	8	01	"	I	Ec. Re.		6	51	"	I	Sh. In.
11	5	12	"	I	Sh. Eg.		8	05	"	I	Tr. Eg.
13	6	21	"	II	Oc. Dis.	26	6	21	"	I	Ec. Re.
14	6	17	"	III	Tr. Eg.						

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

1893.

Feb. 4 11 P. M.
9 11 "
14 11 "
19 10 "
24 10 "

ALGOL.

R. A.....$3^h\ 01^m\ 01^s$
Decl.....$+40°\ 32'$
Period.....$2d\ 20^h\ 49^m$

Feb. 14 11 P. M.
17 8 "

R. CANIS MAJORIS.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$-16°\ 11'$
Period.....$1d\ 03^h\ 16^m$

Feb. 1 9 P. M.
8 5 "
9 8 "
10 11 "
17 7 "
18 10 "
25 6 "
26 9 "
28 12 "

S CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....$+19°\ 26'$
Period.....$9d\ 11^h\ 38^m$

Feb. 10 5 P. M.
20 4 A. M.

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....$-28°\ 09'$
Period..... $7^h\ 47^m$

Feb. 1 9 P. M.
2 5 A. M.
2 8 P. M.
3 3 A. M.
4 2 "
5 2 "
6 1 "
7 12 "
7 12 P. M.
8 11 "
9 10 "
10 10 "
11 9 "
12 5 A. M.
12 9 P. M.
13 4 A. M.
14 4 "
14 7 P. M.
15 4 A. M.
16 2 "
17 2 "
18 1 "
19 12 "
19 12 P. M.
20 11 "
21 10 "
22 10 "
23 9 "
24 5 A. M.
24 8 P. M.
25 4 A. M.
25 8 P. M.
26 3 A. M.

S ANTLIÆ CONT.

Feb. 26 7 P. M.
27 3 A. M.
28 2 "

δ LIBRÆ.

R. A.....$14^h\ 55^m\ 06^s$
Decl.....$-8°\ 05'$
Period.....$2d\ 7^h\ 51^m$

Feb. 3 6 A. M.
10 5 "
17 5 "
24 4 "

U CORONÆ.

R. A.....$15^h\ 13^m\ 43^s$
Decl.....$+32°\ 03'$
Period.....$3d\ 10^h\ 51^m$

Feb. 3 12 A. M.
20 7 "
27 4 "

U OPHIUCHI.

R. A.....$17^h\ 10^m\ 56^s$
Decl.....$+1°\ 20'$
Period.....$0d\ 20^h\ 8^m$

Feb. 4 5 A. M.
5 2 "
9 6 "
10 2 "
14 7 "
15 3 "
20 4 "
20 12 P. M.
25 5 A. M.
26 1 "

Phases and Aspects of the Moon.

	d	h	m	
Last Quarter	Feb. 8	2	12	P. M.
Apogee	" 8	9	48	"
New Moon	" 16	10	17	A. M.
Perigee	" 21	2	42	P. M.
First Quarter	" 23	8	14	A. M.

COMET NOTES.

The comet announced by Freeman Nov. 24, appears to have been a nebula.

Holmes' comet is growing rapidly fainter but has expanded and become very diffuse. There is a slight condensation about the nucleus, 1′ or more in diamete., which is about all that can be distinguished with a large telescope. With a four or five-inch telescope and very low power the nebulosity is seen to extend over a width of from 15′ to 20′ and a length of nearly 2°. If the comet keeps on diminishing in brightness it will soon be beyond the possibility of accurate measurement. Our last observation was on the night of Dec. 23.

Brooks' comet *d* 1892, is quite bright, but is now too far south for observation in this latitude.

Brooks' last comet *g* 1892 should be growing brighter according to an ephemeris which we have extending to Dec. 31. It is now visible in the morning, but in January will be continually above the horizon. Jan. 1 it will be in the constellation of Draco just south of the Little Bear.

Course of Holmes' Comet during the Summer of 1892.—In *Astr. Nach.*, No. 3133, Mr. Berberich gives the following ephemeris of the path of Comet Holmes during the past summer, with the hope of finding its impression upon some of the photographs which may have been taken. It is reported that several amateurs saw the comet prior to Nov. 6, but supposed it to be a known nebula. We learn from *The Observatory*, December, 1892, that Mr. Schooling has found a trace of the comet on one of his photographs taken at Hammersmith, Eng., Oct. 18.

Berlin Midnight. 1892.	R. A. h m	Decl. ° ′	log *r*	log. *Δ*	Br.
May 30	0 15.8	+ 5 20	0.3383	0.3837	0.47
June 19	0 44.5	11 23	0.3372	0.3451	0.56
July 9	1 09.6	17 28	0.3381	0.3029	0.68
29	1 28.7	23 32	0.3409	0.2582	0.83
Aug. 18	1 40.9	29 20	0.3455	0.2149	0.99
Sept. 7	1 40.7	34 32	0.3518	0.1770	1.14
27	1 27.3	38 15	0.3595	0.1535	1.23
Oct. 17	1 05.6	+39 35	0.3685	0.1531	1.18

It will be seen that the theoretical brightness of the comet was not much greater at the maximum in September than it was at the time of discovery, so that it is not so wonderful after all that the comet was not seen earlier.

Elements of Comet *f* 1892 (Holmes).—Numerous computers have been at work on this comet. The best elements which we have at hand are the following:

Computer.	Kreutz. Berlin M. T.	Berberich. Berlin M. T.	Schulhof. Paris M. T.
T	1892 June 9.9978	June 20.7357	July 15.6550
ω	13° 37′ 49″.0	18° 12′ 14″.8	31° 27′ 58″.4
Ω	331 31 03 .7	331 04 23 .2	328 32 40 .7
i	20 54 08 .1	20 39 38 .8	20 26 46 .8
ε	0.417209	0.393144	0.355386
μ	500″.407	523″.335	.....
log *a*	0.567123	0.554151	.....
Period	7.09 years	6.78 years	6.72

The first set of these elements represents the observations quite closely up to Dec. 23, the corrections to the ephemeris on that date being + 13ˢ in R. A. and

+ 0′.4 in Decl. We give below an ephemeris for January based upon these elements. Mr. Berberich's elements represent the observations better in R. A. but not quite so well in Decl. Mr. Berberich points out the fact that according to his elements, the eccentricity of this orbit is smaller than that of any other known comet. Its aphelion distance 5.0 is less than the distance of Jupiter from the Sun and its perihelion distance greater than that of Mars. Its path is almost wholly within the Asteroid zone. This suggests the query, which has frequently occurred to us when considering the unusual behavior of this comet, whether it may be the result of a collision between two asteroids. Mr. Corrigan, on another page in this journal, even goes so far as to seek to find the particular pair of asteroids to which the catastrophe has happened.

Ephemeris of Comet *f*, 1892 (Holmes).

		App. R. A.			App. Decl.		log Δ	log r	Br.
		h	m	s	°	′			
Jan.	5.5	1	08	08	+ 33	48.8	0.3505	0.4199	0.17
	6.5		09	15		47.3			
	7.5		10	23		46.0			
	8.5		11	32		44.8			
	9.5		12	42		43.6	0.3621	0.4224	0.16
	10.5		13	53		42.6			
	11.5		15	05		41.7			
	12.5		16	18		40.9			
	13.5		17	31		40.3	0.3736	0.4250	0.15
	14.5		18	46		39.8			
	15.5		20	01		39.3			
	16.5		21	17		39.0			
	17.5		22	34		38.8	0.3849	0.4275	0.14
	18.5		23	32		38.7			
	19.5		25	11		38.7			
	20.5		26	31		38.8			
	21.5		27	51		39.0	0.3960	0.4300	0.13
	22 5		29	12		39.4			
	23.5		30	34		39.8			
	24.5		31	57		40.3			
	25.5		33	20		40.9	0.4068	0.4325	0.12
	26.5		34	44		41.6			
	27.5		36	09		42.4			
	28.5		37	34		43.3			
	29.5		39	00		44.2	0.4175	0.4350	0.11
	30.5		40	27		45.3			
	31.5		41	54		46.4			
Feb.	1.5		43	22		47.6			
	2.5		44	50		48.9	0.4279	0.4375	0.11
	3.5		46	19		50.3			
	4.5		47	49		51.7			
	5.5		49	19		53.2			
	6.5	1	50	50	+ 33	54.7	0.4382	0.4400	0.10

Comet *f*, 1892.—The famous comet Holmes (supposed by some to be the last one of Biela) has been observed here on nearly every clear night since we received the telegram announcing its discovery. This object seemed to increase in size rapidly until Nov. 20, and was then apparently traveling rapidly towards the Earth. It was the most brilliant on Nov. 20th and was distinctly visible to the naked eye, being a little to the south of the nebula in Andromeda. The comet had a well defined nucleus and a very large envelope. At times I thought I could see faint traces of a tail on the following side. After November 20th the comet rapidly grew fainter, and is now on moonlight nights quite difficult to find. The comet's right ascension and declination have changed but little since Nov. 9th, the first night it was observed here. FRANK E. SEAGRAVE.

Providence, Nov. 29th, 1892.

Elements of Comet *g* 1892 (Brooks Nov. 18).—From *Science Observer Special Circular* No. 100 we have the following elements and ephemeris of Brooks' last comet, computed by Dr. S. C. Chandler from observations at Cambridge and Cincinnati Nov. 21, 22, 24, 29, 30.

$$\begin{aligned} T &= 1893 \text{ Jan. } 7.67258 \text{ Gr. M. T.} \\ \omega &= 81^\circ\,07'\,02''.6 \\ \Omega &= 183\ 29\ 13\ .8 \\ i &= 141\ 18\ 00\ .1 \\ \log q &= 0.095144 \end{aligned} \quad \left.\begin{matrix}\\ \\ \\ \\ \end{matrix}\right\} \text{Eq. Nov. } 26.5$$

EPHEMERIS.

Gr. Midnight	App. R. A.	App. Decl.	log Δ	Br.
	h m s	° ′		
1892 Dec. 7.5	13 26 17	+ 23 23	0.1155	1.79
11.5	13 36 20	27 07	0.0764	2.21
15.5	13 48 49	31 38	0.0354	2.75
19.5	14 05 04	37 05	9.9937	3.41
23.5	14 27 22	43 34	9.9538	4.18
27.5	15 00 24	50 56	9.9191	5.30
31.5	15 51 38	58 36	9.8939	5.66

Ephemeris of Comet *d* 1892 (Brooks Aug. 28).

From Hill's elements as given in A. J. Vol. XII, p. 119, I have computed the following ephemeris:

G. M. T.	App. R. A.	App. Decl.	Log. *r*.	Log. Δ.
	h m s	° ′		
1893. Jan. 1.5	14 23 4	− 38 44	9.9928	0.0123
2.5	28 31	39 5		
3.5	33 57	39 25		
4.5	39 21	39 44		
5.5	44 42	40 0	9.9962	0.0260
6.5	50 0	40 16		
7.5	14 55 15	40 31		
8.5	15 0 27	40 45		
9.5	5 36	40 58	0.0017	0.0395
10.5	10 42	41 9		
11.5	15 45	41 20		
12.5	20 45	41 30		
13.5	25 42	41 39	0.0090	0.0526
14.5	30 34	41 46		
15.5	35 23	41 53		
16.5	40 8	42 0		
17.5	44 50	42 5	0.0179	0.0651
18.5	49 28	42 9		
19.5	54 2	42 13		
20.5	15 58 32	42 16		
21.5	16 2 58	42 19	0.0282	0.0769
22.5	7 20	42 20		
23.5	11 38	42 22		
24.5	15 52	42 22		
25.5	20 1	42 22	0.0396	0.0879
26.5	24 6	42 21		
27.5	28 7	42 20		
28.5	32 5	42 19		
29.5	35 58	42 17	0.0520	0.0981
30.5	16 39 47	− 42 14		

O. C. WENDELL.

Harvard College Observatory, Dec. 14, 1892.

Ephemeris of Comet *d* 1892 (Brooks).

From *Astr. Nach.* No. 3131.

Berlin midn. 1893		App. R. A. h	m	s	App. Decl. °	′	log. *r*	log. *Δ*	Br.
Jan.	8	15	02	19	− 40	43.8	9.9982	0.0374	19.47
	9		07	29	40	56.1			
	10		12	37	41	07.4			
	11		17	41		17.6			
	12		22	41		26.9	0.0052	0.0508	17.73
	13		27	38		35.2			
	14		32	32		42.7			
	15		37	22		49.3			
	16		42	08	41	55.1	0.0138	0.0636	16.07
	17		46	50	42	00.1			
	18		51	29		04.3			
	19	15	56	03		07.8			
	20	16	00	33		10.5	0.0239	0.0757	14.51
	21		04	59		12.6			
	22		09	20		14.0			
	23		13	37		14.7			
	24		17	50		14.9	0.0352	0.0869	13.07
	25		22	00		14.5			
	26		26	06		13.6			
	27		30	08		12.1			
	28		34	06		10.2	0.0474	0.0974	11.78
	29		38	00		07.8			
	30		41	49		05.0			
	31		45	35	42	01.7			
Feb.	1		49	16	41	58.1	0.0604	0.1070	10.61
	2		52	53		54.1			
	3		56	26		49.8			
	4	16	59	55		45.2			
	5	17	03	19		40.2	0.0740	0.1157	9.57
	6		06	39		34.9			
	7		09	55		29.4			
	8		13	06		23.6			
	9		16	14		17.6	0.0879	0.1236	8.66
	10		19	18		11.4			
	11		22	19	41	04.9			
	12		25	16	40	58.2			
	13		28	09		51.3	0.1020	0.1306	7.86
	14		30	58		44.3			
	15		33	44		37.0			
	16		36	25		29.6			
	17		39	03		22.1	0.1163	0.1367	7.16
	18		41	37		14.5			
	19	17	44	08	40	06.8			
	20	17	46	35	39	59.0			
	21		48	58		51.1	0.1305	0.1420	6.54
	22		51	18		43.1			
	23		53	34		35.1			
	24		55	46		27.0			
	25	17	57.	55		18.7	0.1446	0.1465	6.00
	26	18	00	01		10.4			
	27		02	05	39	02.0			
	28	18	04	05	−38	53.5			

Meteors of Nov. 23, 1892.—Happening to look up for the comet in Andromeda at $6^h\ 55^m$ P. M., Pacific Standard time, I saw several meteors of short course appearing to radiate from a point very close to the S. E. part of the nebula of Andromeda. In five minutes I saw fifty in the immediate vicinity. I then called three members of a family so as to command the sky to the north, east and partly to the west and also to the southward about ten or twelve degrees from

the radiant. We lost five minutes and then continued the count from the first fifty. At $7^h\ 32^m$ we had counted 300; at $8^h\ 03^m$, 700; and the eighth hundred was counted in the next seven minutes. I left the observing to the other watchers who reported a total of 1,205 at $8^h\ 36^m$, with the meteors falling as fast as before. One of the later hundreds was counted in six minutes. Frequently three and four meteors were visible at once, and sometimes five. Many of the meteors were faint with short quick courses, others were bright, about third a second magnitude, with quick courses of five to seven degrees. One very bright one, about first magnitude had a quick course of ten degrees and left a bright trail that lasted fifteen seconds.

One moderately bright meteor blazed out nearly at the radiant with a course only one degree long. A faint one grazed the south side of the nebula. Some few of the courses were apparently curved, and some very decidedly zigzag. The earlier meteors radiated from a point close to the S. E. part of the nebula of Andromeda; at the close of our observations and at 9 o'clock the radiant had a position five or six degrees east of the nebula and about half a degree south.

At 9:10 a few minutes watching satisfied me the shower continued nearly as strong as at 8 P. M. At ten o'clock the numbers were much reduced.

These observations were made at my home near the Observatory; Mr. Chas B. Hill at the Observatory commenced observing the meteors at $7^h\ 30^m$. He watched only the southeastern heavens and counted 100 meteors in nine minutes. Had there been another observer looking to the southwest, we may reasonably expect that an equal number would have been seen in that direction. The part towards the northwest not commanded by us may be assumed to have shown one-half those seen by Mr. Hill. Combining these four areas there would have been observed 3,600 meteors in the ninety-six minutes of our watching. Many small ones must have been overlooked.

I kept my eyes directed mainly towards the radiant and obtained many minute meteors; those seen low down were generally larger. From 12:05 to 12:35, past midnight, I watched very carefully and saw twenty-two meteors of which two or three were not conformable. It was somewhat difficult to fix the radiant but it was not less than eight degrees east of the nebula of Andromeda and probably one degree south. A few of the meteors were small, but the most were about the second or third magnitude. All the courses were quick and three to five degrees long. I commanded a limited region about the radiant. One meteor exhibited half a dozen bright points immediately behind it and thence further was the usual luminous streak. All meteors leave an impression upon me that they are high up in the atmosphere but at 12:30 one crossed just above what I had decided was the radiant; it had no visible head and was a rather faint streak of light with much swifter movement than any other of this shower through a course fifteen degrees long, and it left the decided impression that it was very close to the Earth.

The whole evening was very clear and stars of sixth magnitude were easily visible.

Through the evening of the 24th I watched at intervals until midnight but saw only a few meteors non-conformable to the radiant of those of the 23rd. The 25th was quite hazy and only the second and third magnitude stars visible but no meteors. 26th. Heavy clouds. 27th. Southeastern a few openings about 11 P. M. but no meteors were seen. GEORGE DAVIDSON.

Davidson Observatory, San Francisco, Cal.

Meteors of Nov. 23, 1892.—A great meteoric shower was observed here on Wednesday evening the 23d. The shower commenced here about nine o'clock and lasted until nearly midnight. Between ten and eleven o'clock over four hundred meteors were counted. Instead of radiating from Andromeda they seemed to radiate more from the great square in Pegasus. Most of these meteors moved in a north and northwesterly direction. On the nights of November 27th and 28th the meteors were few here, and none of any great brilliancy were seen. Possibly the fragments of Biela's comet are due early every revolution.

Providence, Nov. 29th, 1892. FRANK E. SEAGRAVE.

Solar Eclipse of Oct. 20, 1892.—This eclipse was observed at the Chamberlin Observatory with the 6-inch equatorial, equipped with a polarizing solar eyepiece, and a magnifying power of 200 diameters.

At the first contact the definition was fair, but the Sun's limb was trembling somewhat. The notch was surely seen: the serrations of the Moon's limb were very marked. At the last contact the Sun's limb was more disturbed than at the first, but yet the observation was accounted satisfactory. The times were noted by the eye and ear method. At times during the eclipse the cusps were very sharply defined; there was nothing to suggest the suspicion of a lunar atmosphere.

Miss Edna Iliff observed the last contact with a five-inch Clark glass, equipped with a Herschel solar eyepiece, the magnifying power being 61 diameters. She recorded the time on the chronograph. The local mean times are given.

	Ch. Obs. M. T.	Observer.
First Contact.....Oct. 19	$21^h\ 50^m\ 52^s.5$	H. A. H.
Last Contact.....	23 53 42 .6	H. A. H.
Last Contact.....	23 53 37 .5	E. I.

Denver, Colo. HERBERT A. HOWE.

Seven New Asteroids.—The superiority of the photographic over the old method of discovering new asteroids is well shown by the number discovered in November by the new method, at Heidelberg and Nice. 1892 L was found in November on plates which were exposed August 23 and 29 by Dr. Wolf at Heidelberg. It was observed by Palisa at Vienna, Nov. 22, being found by the aid of a circular orbit which Dr. Berberich calculated from the photographed positions. The following is the list of photographs and first positions:

	Photograph.				First Position.			
1892.	By	At	Date	Mag.	Gr. M. T	App R. A.	Decl.	
					h m	h m s	° ′ ″	
L	Wolf	Heidelberg	Aug. 22, 29	13.	Aug. 22	12 05	23 23 53.5	— 7 03 32
M	Charlois	Nice	Nov. 15, 16	11.5	Nov. 20	6 03	2 12 28.4	+ 10 02 09
N	Wolf	Heidelberg	Nov. 15, 20	——	Nov. 15	9 37	4 10 34.6	+ 23 34 49
O	Charlois	Nice	Nov. 23, 24	11.0	Nov. 24	7 47	2 47 43.3	+ 10 12 10
P	Charlois	Nice	Nov. 25	11.0	Nov. 27	7 08	3 37 47.9	+ 11 27 53
Q	Charlois	Nice	Nov. 28	12.0	Nov. 29	7 39	3 50 54.1	+ 12 23 37
R	Charlois	Nice	Nov. 28	12.5	Nov. 29	8 03	3 59 30.7	+ 13 29 10

Transit of Mercury, May 9, 1891.—As observed at the Davidson Observatory, San Francisco, Cal., Latitude = 37° 47′ 24″.1; Longitude = $8^h\ 09^m\ 42^s.75$.

Observer, Professor George Davidson, U. S. Coast and Geodetic Survey, using the 6.4-inch Clark equatorial (reduced to 4¼-inches) with eye-piece magnifying 130 diameters, and double wedge of colored glass showing Sun white. Sidereal chronometer No. 3479, fast of local sidereal time 33.56 seconds.

I contact = $6^h\ 54^m\ 04^s.2$ by chronograph. Observation good. No sign of Mercury for three minutes before I, although looking at exact spot of contact.

II contact = $6^h\ 58^m\ 24^s.5$ by chronograph. Limbs very unsteady. No light interval between limbs. Black drop. Time not close on account of the atmospheric unsteadiness. I assume this time to represent the geometrical contact.

$6^h\ 58^m\ 51^s$ by chronometer: absolutely wide opening between the limbs of Sun and planet.

Observer, Mr. F. W. Edmonds, using Hassler equatorial 3-inches aperture-eye-piece magnifying 60 diameters. Sidereal chronometer No. 211, slow of local sidereal time = $13^m\ 52^s.13$:

I contact, lost.

II contact = $6^h\ 44^m\ 16^s.5$ by chronograph.

Observer, Mr. T. D. Davidson, using 3-inch Fraunhöfer, power 60 diameters. Mean time chronometer No. 5038, fast of local mean time $5^m\ 43^s.10$:

I contact, lost.

II contact = $3^h\ 54^m\ 00^s$ by chronograph.

Observer, Mr. A. P. Redington, using 3-inch Clark, power 60 diameters, sidereal chronometer No. 380 slow $2^h\ 38^m\ 22^s.75$ of local sidereal time:

I contact, lost (first seen $4^h\ 16^m\ 04^s$ by chronograph).

II contact = $4^h\ 19^m\ 50^s$ by chronograph.

Observer, Mr. Chas. B. Hill, using private 6 inch equatorial of Captain Chas. Goodall, situated 45″.0 south and $1^s.7$ west of the Davidson Observatory, (or in Latitude 37° 46′ 39″.1; Longitude $8^h\ 09^m\ 44.4^s$). Solar prism and mean time chronometer No. 231, fast of Davidson Observatory mean time = $2^s.37$:

I contact = $3^h\ 44^m\ 13^s$ by chronometer. First seen when well on (estimated 20^s) wind shaking building and telescope violently, image continually oscillating four and five minutes of arc. Power 65 diameters.

II contact, $3^h\ 47^m\ 43^s$ close to contact; $3^h\ 48^m\ 01^s$ certainly past. The two times of contact are two epochs of fairly distinct vision and limit the true contact. I take the mean as the best possible under the circumstances. Wind continually jarring telescope and observation well-nigh impossible. Power 130 diameters.

The local time was determined by Mr. Hill at the Davidson Observatory on the evenings of May 7, 8 and 9. The chronometers were compared before and after the transit by Mr. Edwards, and the rates of the standard chronometer and sidereal clock agreed at the time within five one-hundredth seconds.

A summary of the observations is given in a table below:

Observer.	I Contact.		II Contact.	
	Local Sidereal Time.	Pacific Standard Time	Local Sidereal Time.	Pacific Standard Time.
	h m s	h m s	h m s	h m s
G. Davidson	6 53 30.6	3 53 13.3	* 6 57 50.9	3 57 32.8
F. W. Edmonds	.....	.....	6 58 08.6	3 57 50.5
T. D. Davidson	.....	.....	6 58 17.8	3 57 59.7
A. P. Redington	.....	.....	6 58 12.7	3 57 54.6
C. B. Hill	** 6 53 50.7	3 53 33.4	6 57 50.5	3 57 32.4

* Geometrical Contact, wide opening, 26.5^s later.

** Estimated from first view 20^s later.

Occultation of *o* Piscium, Nov. 30, 1892.—The immersion was observed by Miss Lottie Waterbury with the 6-inch equatorial of the Chamberlin Observatory, the magnifying power being 96 diameters. I noted the time for her with a sidereal chronometer. The emersion was noted by Miss Edna Iliff, using a five inch Clark

glass, equipped with a magnifying power of 80. The definition was superb, and the star was seen without difficulty. The time of emersion was noted on the chronograph. Both are local mean times.

Immersion.....	4^h	38^m	$45^s.1$
Emersion.....	5	12	18 .3

H. A. HOWE.

NEWS AND NOTES.

This number is sent to some subscribers who have not ordered a renewal of subscription for 1893. It is especially hoped that all orders will be promptly made that the lists for the new yearmay be correct before the close of the present month.

It is a most encouraging fact that the subscription list to this publication increased, during the last year, more than twenty per cent. This, with other signs of possible progress, has led the Editors to seek new and most efficient help for their regular work indicated by the names of the staff on the first cover page. Still another name or names will be added later on. No pains will be spared to secure best results possible for 1893.

One of the most serious hindrances in our work in the past has been, the difficulty we have met in obtaining late important news from the observatories of the United States. This is not because astronomers are not interested in their own work, or the work of others for if we go wrong in regard to notices of either or in any other way we promptly hear from them, generally with the kindest reminders possible, but sometimes we have been criticised most unmercifully. Now, this is proof positive of unusual and unabated interest in what is for the good of our science and its workers. Would it not be a good idea for every astronomer in this country to contribute some brief note or item of general interest for every issue of this publication for this year? We will try to give space for such a summary of current astronomical intelligence in every number in the future.

The Planet Mars.—M. Flammarion has recently published a most interesting and valuable monograph entitled "La Planète Mars et ses conditions d'habitabilité." The author has endeavored to collect into one volume all the information which is to be obtained from all the observations which have been made up to the present time. The volume is illustrated with nearly 600 copies of drawings and 23 charts of the planet. It is interesting to look over these drawings and note the gradual increase in accuracy and amount of detail seen with the improvement of the telescope. The first drawings we find are those of Fontana in 1636 and 1638. These show no detail on the surface of the planet. The markings shown are evidently due to optical defects in his telescope. The first really good drawings which we find are those of Father Secchi made at Rome in 1858 with a 9-inch refractor.

It would be impossible to give a complete review of the work here. It will suffice to say that the author, having collected all the available observations up to, and partly including 1892, gives a careful discussion of the material, treating of the surface conditions, climate, seasons, conditions of habitability, etc., in a manner which makes the book pleasant reading, and so completely as to make it invaluable as a source of information concerning the planet.

XUM

Astronomy, Physics and Chemistry in Primary and High Schools.—At its last annual meeting the National Educational Association raised a committee of ten with President Eliot, of Harvard University, as Chairman, to consider ways and means by which a uniform preparation for College and University may be secured in secondary schools in the United States. Ten persons selected from different parts of the United States have been asked to serve on each of nine different topics, one of which is "Astronomy, Physics and Chemistry." The persons selected for this committee are as follows:

Professor Brown Ayres, Tulane University, New Orleans, La.
Irving W. Fay, The Belmont School Belmont, Calif.
Alfred P. Gage, English High School, Boston, Mass.
Professor William W. Payne, Carleton College, Northfield, Minn.
W. C. Peckham, Adelphi Academy, Brooklyn, N. Y.
William McPherson, Jr., 2901 Collinwood Ave., Toledo, O.
Professor Ira Remsen, Johns Hopkins University, Baltimore Md.
Professor James H. Sheppard, South Dakota Agricultural College, Brookings, So. Dak.
Professor William J. Waggoner, University of Colorado, Boulder, Colo.
George R. White, Phillips Academy, Exeter, N. H.

This committee is to meet in Chicago, Cobb's Hall, Chicago University, December 28, for the discussion of a series of questions suggested by the general committee before referred to. When the report of the committee is completed, it will be published, for we anticipate some important changes will be advised in regard to teaching these branches in Secondary and Primary schools.

Double Star Observations.—Mr. W. H. Maw publishes in the Memoirs of the R. A. S., Vol. L, his double star observations during 1888-91, the reprint of which we have just received. The measures were made with a 6-inch Cooke refractor and filar micrometer, and appear to be very accurate. The list of 153 stars consists mostly of the doubles discovered by Σ and $O\Sigma$ but includes some of Burnham's close pairs.

Publications of the Cincinnati Observatory No. 12—This is a most valuable catalogue of 1340 stars having proper motions greater than 0.15″, by J. G. Porter, the Director of the observatory. Professor Porter has collected all the available observations of each star and has re-observed with the new Meridian Circle all except those which were too far south in declination. All the observations have been reduced to the epoch 1900 and published in convenient form for reference. Except in the case of the Berlin Jahrbuch stars the proper motions have all been determined anew. We notice a large proportion of 8th to 9th magnitude stars, the motions of which, from a cursory examination, do not appear to be less than those of the brighter stars At the end of the publication is given a catalogue of the resulting positions for 1900, together with the precession, secular variation and proper motion in right ascension and declination. We miss, however, a list of the proper motions reduced to the arc of a great circle. Such a list would be very useful in comparing the motions of stars of different magnitudes.

On page 764, November number of ASTRONOMY AND ASTRO-PHYSICS Professor Porter gives the results of a new determination of the Solar Motion from these stars.

Publications of the Observatory of Lyons.—The latest publication of the Observatory under the direction of M. Ch. Andrè is a memoir entitled "Recherches sur l'Èquation Personelle dans les observations astronomiques de passages" by M. F. Gonnessiat. This is an important research, and M. Gonnessiat appears to have carried it out very thoroughly. In the Memoir he gives a complete history of all previous investigations of personal equation and works over a good deal of the material obtained in them as well as in his own. He finds, as was to be expected, that the systematic errors of the electric method of registering time are much less liable to variation and have a smaller range than those of the eye and ear method. In searching for the cause of personal equation he finds that in the eye and ear method they may be considered as four:

1. The rythm of beats in counting time (*rythmic equation*).
2. The persistance of the luminous impression on the retina (*physiological equation*).
3. The lack of co-ordination of two different perceptions (*psycho-physiological equation*).
4. The tendency to estimate fractions of seconds in a systematically erroneous manner, (*decimal equation*).

In the electrical method the author divides the causes as follows:

1. The lack of apparent coincidence between the axis of the wire and the center of the star at the instant when the observer decides to press the key, (*equation of bisection*).
2. The persistance of the luminous impression, (*physiological equation*).
3. The time that it takes the impression received by the eye to determine the action of the muscles of the hand, (*psycho-physiological equation*).

The author attempts to give the limiting values of the errors which may be produced by these causes in the following tables:

Eye and Ear Method.

	s	s
Rythmic equation	—0.15	to + 0.30
Physiological equation	—0.05	to + 0.00
Psycho-physiological equation	—0.15	to + 0.05
Decimal equation	—0.05	to + 0.05
Limits of total equation	—0.40	to + 0.40
Difference of extremes	0s.80	

Electric Method.

	s	s
Equation of bisection	—0.10	to + 0.10
Physiological equation	—0.05	to + 0.00
Psycho-physiological equation	—0.20	to + 0.05
Limits of total equation	—0.35	to + 0.15
Difference of extremes	0s.50	

We have received, at the same time with the above publication, three volumes "of Meteorologie Lyonnaise" for the years, 1887-90. H. C. W.

Editor Astronomy and Astro-Physics:—I am computing the orbit of the double star 70 Ophiuchi, and if any of your readers know of unpublished measures of this star, or of measures that I should not be likely to find, I should be pleased to hear from them. To those who are interested I will gladly send a list of the measures that I have at present. A. D. RISTEEN.

P. O. Drawer S, Hartford, Conn.

To the Editor of Astronomy and Astro-Physics.—Sir: May I ask leave to make one or two remarks on some papers in your issue of November?

Professor Coakley does not seem to have seen Professor H. A. Newton's paper on meteorites in which the author endeavors to discover the nature of their orbits from the phenomena attending their fall. He concludes that they were most probably moving round the Sun in orbits of short period when they encountered the Earth. This theory of course leaves the question whether any of these bodies have come to us from outside the solar system (as assumed by Mr. Lockyer) undecided. Professor Coakley's view would deprive much of the meteoritic theory of its basis.

With respect to Professor Porter's article on "The motion of the Solar System," I wish to remark that I believe small proper motions are largely affected by errors of observation and computation and cannot be relied on for the purpose. I have lately been examining the Pulkova Catalogue and I find an enormous preponderance of proper motions in diminishing right ascension. Even between 18^h and 6^h where the Sun's motion tends to increase the R. A. this preponderance exists though the amount is diminished. Such a preponderance seems to me impossible if the length of the year is rightly computed and there is no error in the amount of precession. We have no similar test for proper motions in declination but it seems probable that they are affected by similar errors. When we are dealing with large proper motions small errors are of little consequence but it is quite otherwise when these motions are small. The slight corrections introduced by Herz and Strobl into Auwers' Catalogue have in many cases changed even the direction of a small proper motion. Truly yours,

W. H. S. MONCK.

Erratum p. 844, line 8, for "Clyton" read "Clifton."

A Monster Telescope.—It seems to be a serious proposition, which we were inclined to doubt when we heard of it through the newspapers, that has been made in Paris, to construct a gigantic reflecting telescope, the mirror of which is to be 10 feet in diameter and the length of the tube 140 feet. It is to be ready for the Exhibition, which is to be held in Paris in 1900. The mirror is to be silver-on-glass. Mr. A. A. Common, in *The Observatory* for November, 1892, discusses some of the difficulties of construction and suggests some modifications of the ordinary form of mounting, to meet the purposes for which this great instrument is evidently intended.

M. Trepiéd, Director of the Observatory of Algiers, also (*Ciel et Terre* Nov. 1, 1892) discusses the magnifying power of such an instrument. The French papers, in announcing the project, made the statement that this instrument would bring the Moon within one metre. M. Trépied shows that with the highest practical power, in the best atmosphere, the Moon would be seen as if it were 25,000 metres or 15 miles distant.

Silvering Glass Mirrors.—Some years ago I had occasion to silver several glass mirrors, and in doing this, I followed a process given in the *Chemical News* for March, 1869. I was inexperienced at that time in all kinds of chemical manipulations, and although the mirrors were not large, the success which attended my work was such as to lead me to receive the statement of the article in the December number of ASTRONOMY AND ASTRO-PHYSICS "that hard-and-fast rules cannot be laid down" with some qualifications.

The process which I employed was given in the *Chemical News* as "Mr. Browning's process." I presume that the directions, as I have them now, were

not copied verbatim, but they have all essential points. I worked at any convenient temperature without experiencing difficulty. I give the directions below.

Prepare three standard solutions. (A) Crystals $AgNO_3$, 90 gr., H_2O, 4 oz. (B) Potassa, pure by alcohol, 1 oz., H_2O, 25 oz. (C) Milk sugar powder, ½ oz.-H_2O, 5 oz. This (C), must be prepared fresh at time of using.

Pour 2 oz. solution (A) into a vessel holding 35 oz. Add ammonia, stirring constantly till a clear solution of the precipitate first thrown down is obtained. Add 4 oz. solution (B). Add ammonia just sufficient to redissolve precipitate. Add water till the bulk reaches 15 oz. Add drop by drop solution (A) till a grey precipitate is formed which does not dissolve after three minutes stirring. Add 15 ounces more distilled water. Let it settle. Do not filter. When the mirror is ready, add 2 oz. solution (C) and stir throughly. (Solution (C) may be filtered).

Cement pieces of cork to the back of the mirror as handles. Pour on the surface strong nitric acid and rub it all over with a brush made by plugging a glass tube with pure cotton wool. Clean thus thoroughly the surface and edges, wash well with common water, and then with distilled water, and then lay face downward in spirits of wine (strong) till silvering fluid is ready.

Immerse the mirror face down in solution, so that it may rise about one-eighth of an inch on the edges, avoiding bubbles beneath. Let it remain an hour or two. Then wash immediately with a large quantity of water, then with distilled water. Place on edge on absorbent paper to drain and dry. Polish with gentle rubbing with softest wash leather. Finishing with same dusted with thoroughly dried rouge obtained by stirring rouge in water, pouring off what does not settle in fifteen minutes, and collecting in filter.

My principal difficulty was in cleansing the mirror. I found it advantageous to use strong nitric acid, strong ammonia, and water in succession several times, ending with distilled water, and immersion in alcohol. The difficulty in this was a resulting elevation of temperature requiring that the water be not cold, or the changes of temperature loosened the cemented handles. Obviously heavy mirrors would require special precautions and widely different methods of support.

A very little tartrate of copper proved a desirable addition to the silver solution. I have no record of the proportion added, but it was very little.

CHAS. H. CHANDLER.

Chicago Academy of Sciences, Section of Mathematics and Astronomy.—The regular meeting of the Section was held at the Kenwood Observatory on Tuesday evening, Dec. 6th, 1892. Mr. Douglass presided.

Mr. S. W. Burnham read a paper on astronomical observations with large telescopes. After describing some of the larger refracting and reflecting telescopes Mr. Burnham discussed the relative merits of large and small instruments, concluding that other things being equal the size of a telescope is a direct measure of its power and usefulness. Certain writers have recently attempted to show that large telescopes have not proved wise investments, and that no work has been done with them which could not have been equally well performed with smaller apertures. Such statements Mr. Burnham characterizes as absurd. The satellites of Mars and the recently discovered satellite of Jupiter could never have been found with small instruments, and many double stars discovered with the 36-inch on Mt. Hamilton have not been recently measured simply because they are beyond the reach of all other telescopes. It is true that with some large telescopes not much has been accomplished, but this is the fault of the observer and not of the telescope. In light, resolving power and every other important factor large apertures are much superior to small.

XUM

In answer to a question Mr. Burnham expressed his approval of a site near Chicago for the 40-inch Yerkes telescope. He considers that if the new observatory is placed within fifteen or twenty miles of the city it will be as advantageously situated as any other observatory in the United States, with the single exception of the Lick Observatory. The latter enjoys a larger proportion of clear nights, but it is not certain that the best seeing at Mt. Hamilton is much superior to the best seeing at Chicago.

Professor Henry Crew prefaced his paper on recent investigations in the infra-red and ultra-violet spectrum by a review of the researches in this field of Herschel, Becquerel, Abney, Langley and others. He dwelt at greater length on Snow's recent studies of the infra-red spectra of the alkalies, and pointed out the interesting confirmations of Kayser and Runge's predictions from theory as to new lines in the spectra of these substances. Schumann's important photographic investigations in the extreme ultra-violet hydrogen spectrum were next discussed, and reference made to the additions made at the Kenwood Observatory to the number of known lines in the rythmical spectrum of hydrogen. The paper concluded with an account of the studies of Hertz and others on electrical waves. Throughout the paper the illustration recently described by Stoney in the Philosophical Magazine was employed, in order to give a tangible idea of the magnitudes of the minute quantities under discussion.

Professor George E. Hale followed with a short review of attempts which have been made by various astronomers to photograph the corona without an eclipse, and described a new apparatus which he has devised for the same purpose. The method is a modification of that employed by Dr. Huggins, and it is hoped that it may soon be put to a practical test.

A number of photographs of the Moon and various solar phenomena from negatives made at the Kenwood Observatory were shown on the screen and explained, after which the meeting adjourned. GEORGE E. HALE, Recorder.

Astronomical and Physical Society of Toronto.—It is a matter of no little pride to notice the steady growth and interest manifested in the meetings of the Astronomical and Physical Society of Toronto, as the proceedings of the same are published regularly in those excellent daily papers, "The Globe" and the "Toronto Enterprise." These full reports enable the friends of this young society, far and near, to know very particularly what the many active members are doing in study and observation. We have been greatly interested in all the work so far prosecuted and have arranged to give, in the future, fuller reports in this publication than we have been able to do in the past for the want of space. The very complimentary notices of ASTRONOMY AND ASTRO-PHYSICS that appeared in the "Toronto Enterprise," Dec. 17 and in "The Globe" of Toronto, Dec. 19, are favors most highly appreciated.

BOOK NOTICES.

A Treatise on Plane and Spherical Trigonometry and its applications to Astronomy and Geodesy, with numerous examples, by Edward A. Bowser, LL. D., Professor of Mathematics and Engineering in Rutgers College. Boston: Messrs. D. C. Heath & Co,, Publishers.

Until now we have not had the pleasure of seeing a copy of the Trigonometry recently published by Professor Bowser. This book presents a very full course of study, and it is intended to be varied and complete enough for use in the best

technological schools. The examples illustrate every part of the subject, and are chosen to test, not only the student's knowledge of the usual methods of computation, but also his ability to grasp them in the various forms they may assume in practical applications. The fourteen pages given to the solution of trigonometrical equations is a noteworthy feature, and the chapters on De Moivre's Theorem, Astronomy, Geodesy and Polyhedrons will certainly serve to introduce the student to some of the higher applications of Trigonometry not usually found in American text-books. The attention of students and teachers of Trigonometry is called to Professor Bowser's new work as one also suitable for reference in matter of principle, method and especially examples for illustration.

PUBLISHERS' NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year in advance. For foreign countries it is $4.40 per year which is the uniform price. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. Personal checks for subscribers in the United States may be used.

Currency should *always* be sent by registered letter.

Foreign post-office orders should *always* be drawn on the post-office in Northfield, Minnesota, U. S. A.

All communications pertaining to Astro-Physics or kindred branches of physics should be sent to George E. Hale, Kenwood Observatory, of the University of Chicago, Chicago, Ill.

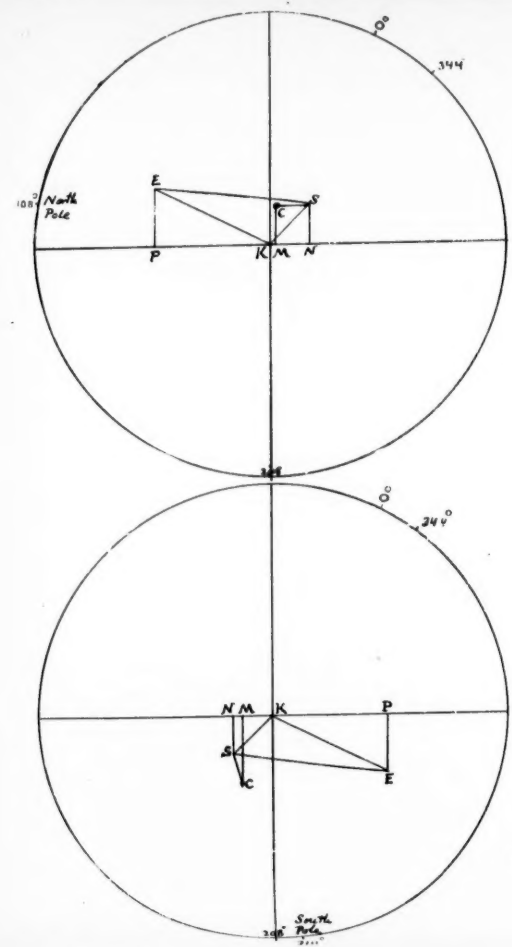
For information of correspondents, the names and addresses of the associate editors of ASTRO-PHYSICS are given as follows:—

James E. Keeler, Observatory, Allegheny, Pa.; Henry Crew, Northwestern University, Evanston, Ill.; Joseph S. Ames, Johns Hopkins University, Baltimore, Md.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher and Proprieter of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.; and the Associate Editors for General Astronomy are: S. W. Burnham, Government Building, Chicago Ill.; H. C. Wilson, Goodsell Observatory, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India Ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. It is requested that manuscript in French or German be typewritten. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.



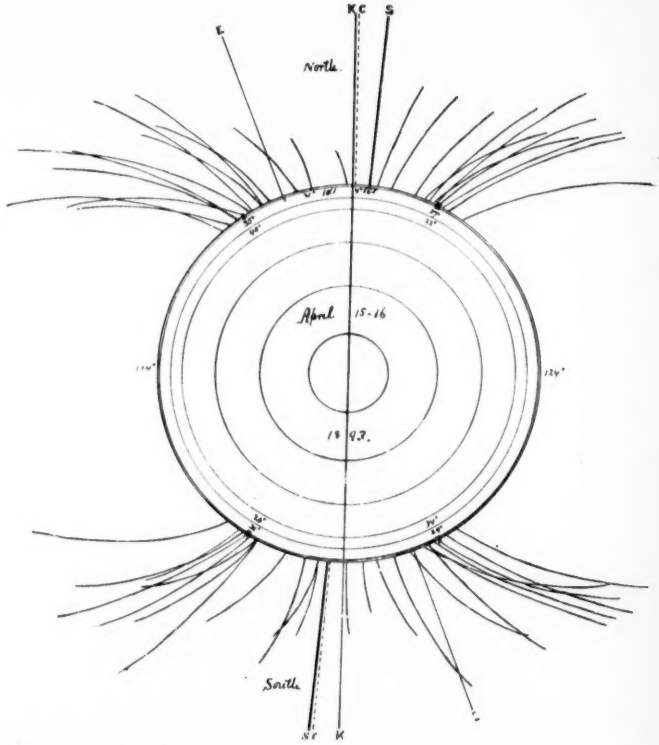


Plate accompanying Professor Bigelow's Paper.